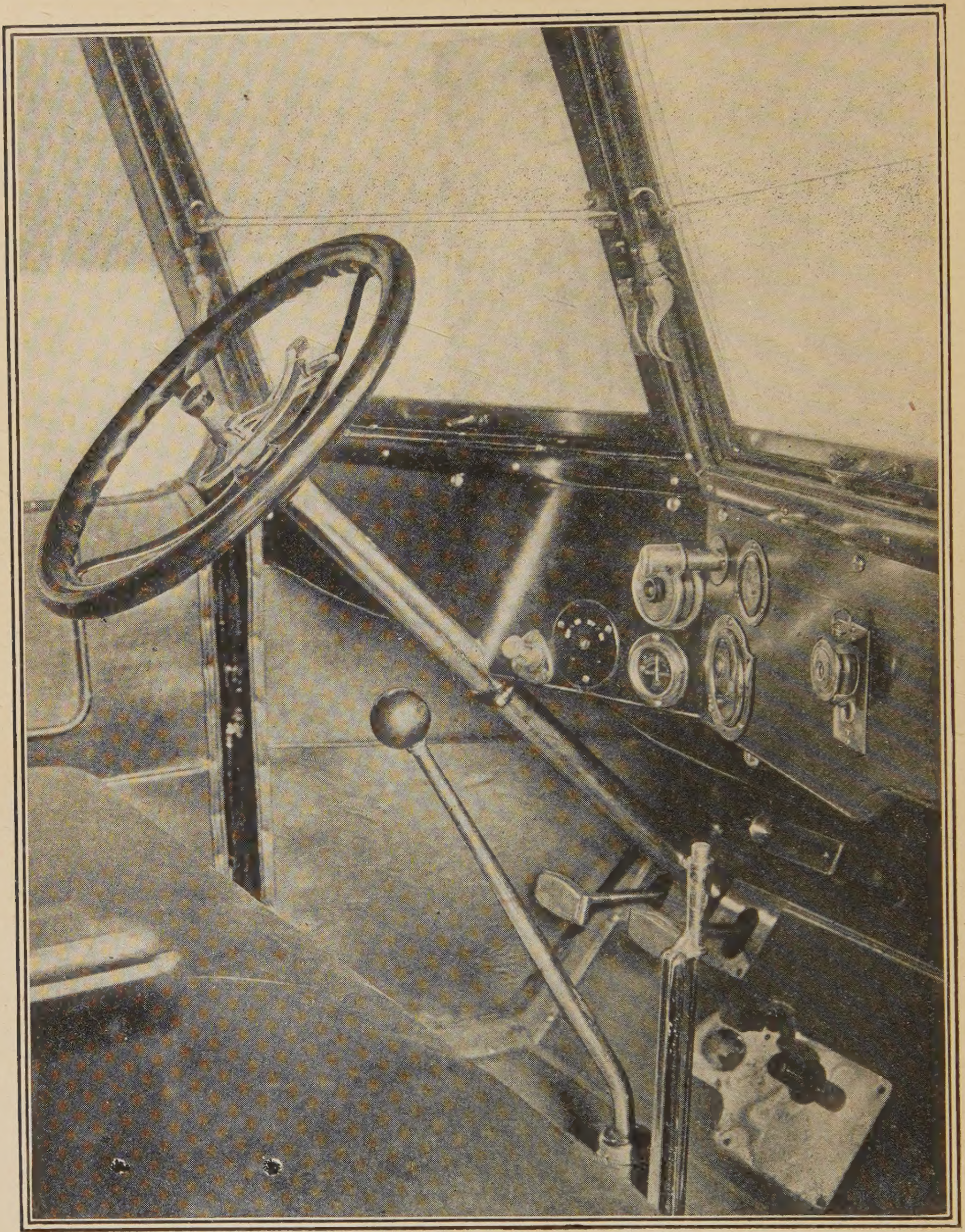
EVERYMAN'S GUIDE TO MOTOR EFFICIENCY

by

H. W. SLAUSON M. E.
AND HOWARD GREENE

SIMPLIFIED SHORT CUTS TO



This is where the salesman leaves you after you have bought the car. You are confronted with dials, gages, levers, pedals and switches used in the control of the car. But this book takes you under the car and into every part influenced by these various controls—all parts are laid bare—and you see the *reason* for everything. Remember,

A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR

EVERYMAN'S GUIDE TO MOTOR EFFICIENCY

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H·W·SLAUSON·M·E·
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SIMPLIFIED SHORT-CUTS TO
MAXIMUM MILEAGE AT MINIMUM COST

1922
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NEW YORK

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Publisher's Foreword

A book, such as this, is as important as gas, oil and tools to the motor car owner. Through sheer worth and practical value this book has won its place as the leading handbook published on the modern automobile. Now in its Fifth Edition, it is about to pass the One hundred thousand mark—a remarkable record for any technical book of necessarily high cost.

The manufacturer of your car has placed in your hands a wonderful piece of mechanism; we are apt to overlook this fact in anything so commonplace as an automobile. Just what you get out of it, in utility and pleasure, now depends upon yourself.

The purpose of this book is to make it possible for you to easily maintain your car in perfect condition; to understand, clearly, its every part; to make it easy for you to get maximum mileage at minimum cost, maximum comfort and utility with a minimum of trouble and inconvenience.

The author, H. W. Slauson, M.E., is one of the leading automotive engineers of the country; chairman of The Metropolitan Section of the Society of Automotive Engineers; Motor Editor of Judge; an authority of national reputation.

There is a simple reason for every part in your car. In this book Mr. Slauson explains the *why* of each part, its construction and functions, just how to maintain each part in first-class operating condition. In the event that trouble does develop, he tells just how to locate it and the *how* of the remedy of the difficulty, no matter how slight or how serious, in terms that are easily understood by everyone.

As a motor car owner or driver, this book will prove to be worth its weight in gold to everyone who makes full use of it.

The Publishers.

Preface

Everyman's car is as good—or as poor—as he makes it. Neglect of adjustments or slight repairs will soon ruin the best car made. A deficient car, on the other hand, may be "nursed" along for thousands of miles and be made to give fairly good service, when you understand its defects and put a little time and thought on their remedy.

This book is not a text-book; nothing in it is to be committed to memory; it is a practical, complete operating and maintenance handbook for the motor car owner who realizes that it is well worth his while to understand his car. The book is full of *practical information* and nothing else.

It tells you what *you* can do when anything goes wrong and the simplest, easiest, quickest way to do it.

It tells you how far the average car owner may go in making his own adjustments and repairs and what jobs are best turned over to garage or service station.

It tells you how to avoid the petty annoyances that too often detract from the value and pleasure of a car and how to maintain your car in the snappy condition in which it was delivered to you.

It is written for everyone who *Owns* a car, *Drives* a car, *Sells* a car, *Repairs* a car. It gets right down to useful facts that are easy to find and plainly labeled.

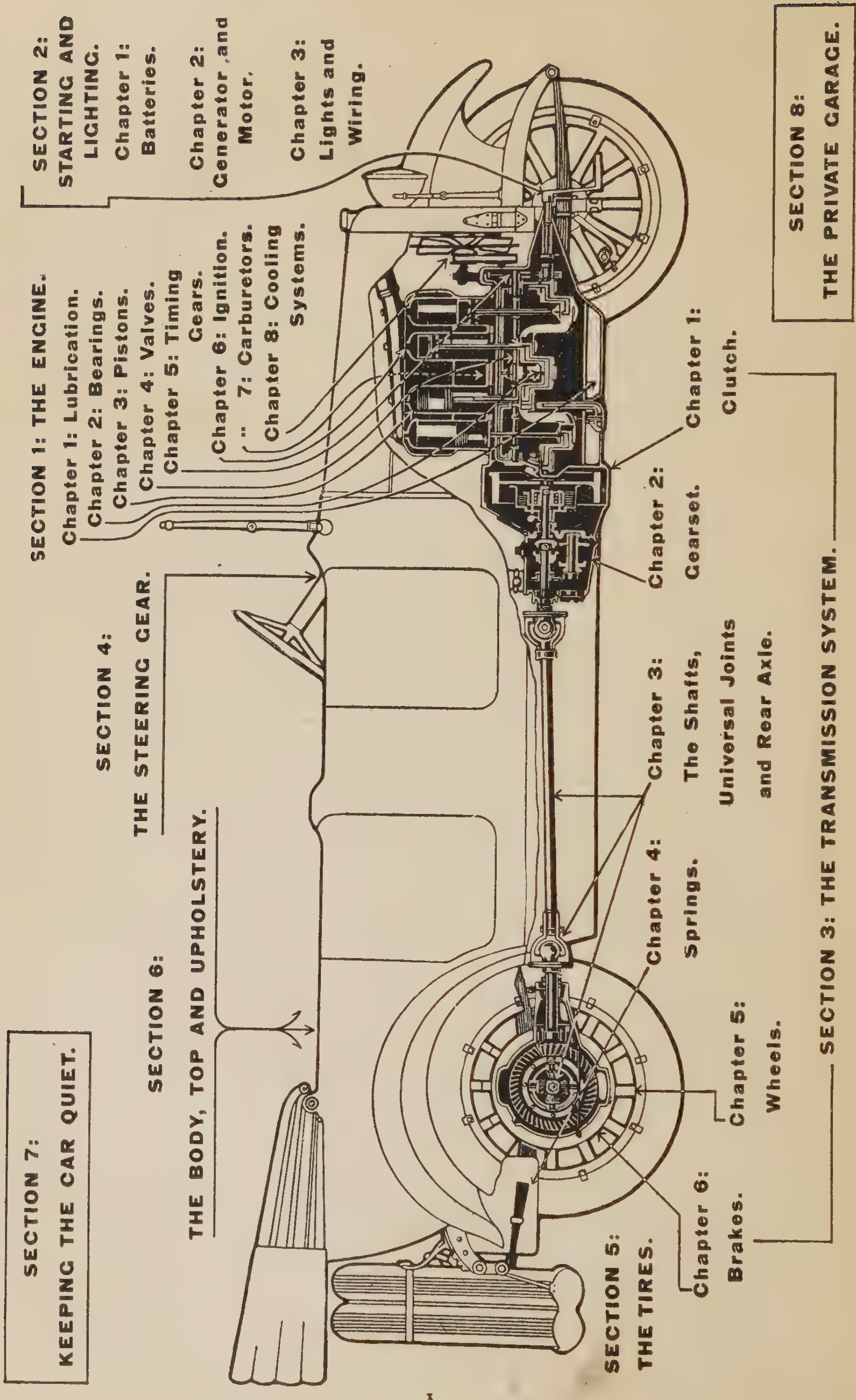
You do not have to thumb through the whole book to find a thing—work direct from the Illustrated Index, the whole book is self-indexing.

Your car may seem like a collection of mysteries; considered as a whole it is a complex piece of mechanism. But it is built up of a number of parts, each of which is simple in itself and easily understood—think of one part at a time and mystery and complexity disappear.

Men who drive their own cars need not be "stumped" at anything; turn to the book, make your diagnosis, apply the remedy.

H. W. Slauson, M.E.

ILLUSTRATED INDEX



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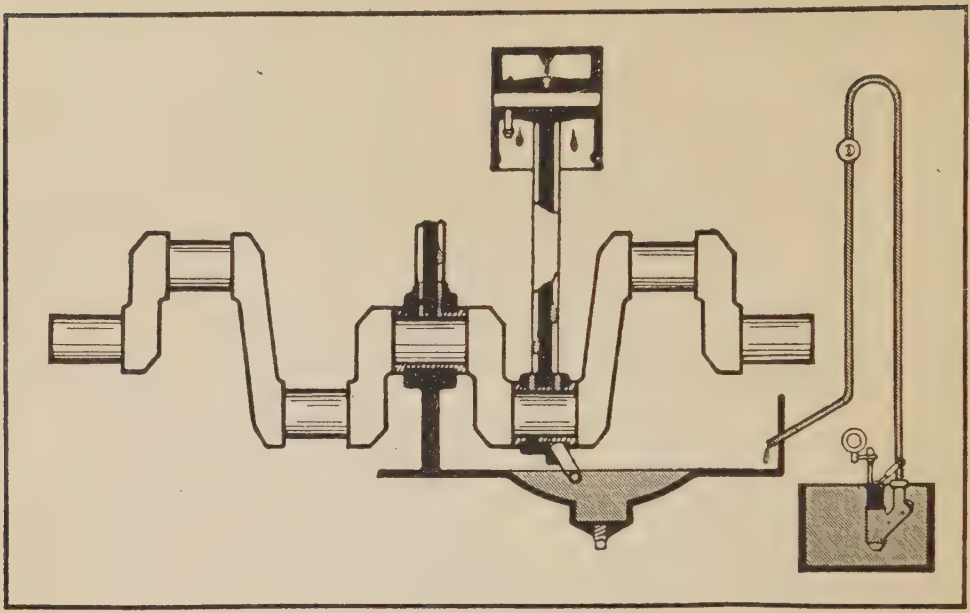
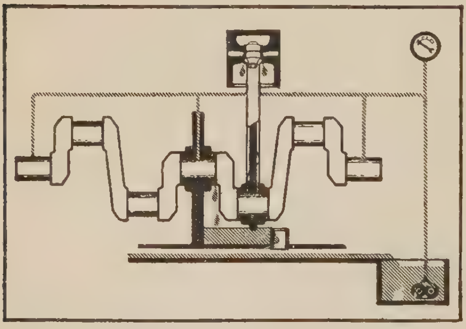
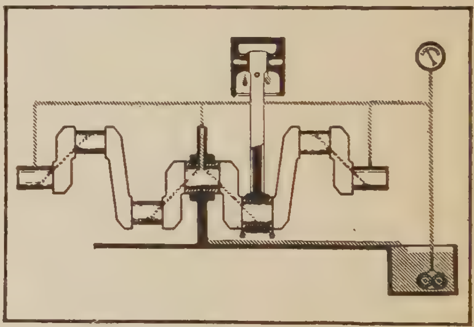


PUMP AND SPLASH—ALL LOSS

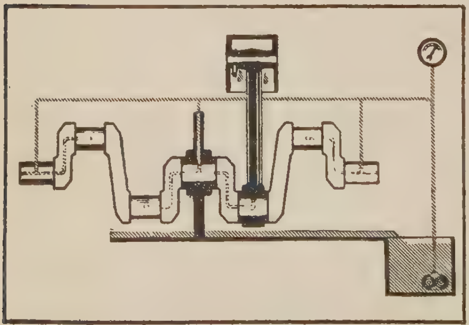
This system is the only one shown here in which the oil does not again reach the reservoir, and is pumped through the system repeatedly until it is consumed.



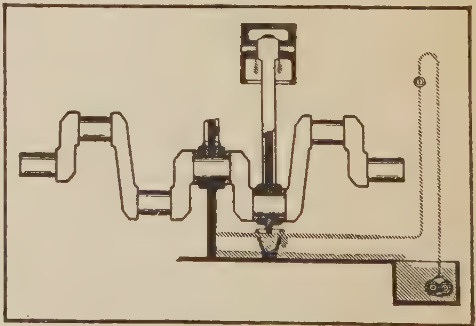
FORCE FEED TO MAIN BEARINGS AND SPLASH TO ALL OTHERS



FORCE FEED TO ALL CRANK SHAFT BEARINGS; SPLASH TO WRIST PIN



COMPLETE FORCE FEED, INCLUDING WRIST PIN



CIRCULATING SPLASH BY PUMP

SECTION I. THE ENGINE

CHAPTER I

LUBRICATION

Object of Lubrication.

Lubrication, whether by oil or grease, is intended to keep moving surfaces separated, so that actual contact of the metals is prevented as far as possible. If it were possible to maintain absolute separation at all times there would be practically no wear. This, however, is not possible, and even under the best of conditions a certain amount of rubbing contact occurs, with consequent wear.

There is no such thing as an absolutely smooth surface. Under the microscope the most highly finished surface it is possible to produce shows a minute roughness, and the rubbing together of two surfaces results in the tearing off of the little high spots. The particles of metal mingle with the oil and in time cause it to deteriorate, even if no other foreign matter gets in.

Using the Right Lubricants.

The best lubricant is that which keeps the surfaces most effectually separated without, however, being so thick or viscuous as to unnecessarily retard motion. No one lubricant is best under all circumstances. Different kinds of mechanism and different mechanisms of the same type require different lubricants. Where the surfaces are small and the pressures heavy it is necessary to use a heavier lubricant than where the surfaces are large and the pressures light. For instance, the teeth of gears usually require a heavy lubricant, such as grease or heavy oil; otherwise the pressure would squeeze the lubricant out and the metals would come together. The pressure of a piston on the cylinder walls, on the other hand, is comparatively light, so a thinner lubricant is used.

The design of an engine, or any mechanism, for that matter, is an exceedingly important factor in deciding upon the lubricant to be used, and in practically all cases manufacturers go to a great deal of trouble to determine what is best.

It is always wise and safe to use the lubricant recommended by the manufacturer.

The large manufacturers of lubricants in many cases have made exhaustive tests and specify the lubricants to be used for various parts of practically all the cars on the market. The charts issued by these concerns are reliable guides to proper lubricants.

Engine Oils.

Under no circumstances must any oil except especially prepared oil be used for the engine. The high temperature quickly makes any other oil useless, no matter how excellent the oil may be for other purposes.

A good oil in the wrong place is a bad oil. Poor oil is bad anywhere. The man who economizes in oil quality pays for it in the wear on his machine, and pays heavily. This is a hard, practical fact and not a theory.

Under normal working temperatures the oil in the engine becomes much thinner than when cold. This is the reason an engine may be stiff and hard to turn over when thoroughly chilled, though it will move freely when warmed up. If the oil is too light when cold it will become so thin when hot that it will fail to separate the moving surfaces—in other words, it loses its lubricating value.

Why the Engine Smokes.

A smoky exhaust is due to the presence above the piston of an excess of oil, which makes a bluish or gray smoke. Too much gasoline in the mixture makes a black smoke. The two smokes are readily distinguished, both by sight and smell.

Smoke from lubricating oil is due to:

An over-supply of oil.

The use of the wrong kind of oil.

Wear of pistons, of cylinder walls, or of both.

Broken, defective or inefficient piston rings.

How to Stop Smoking.

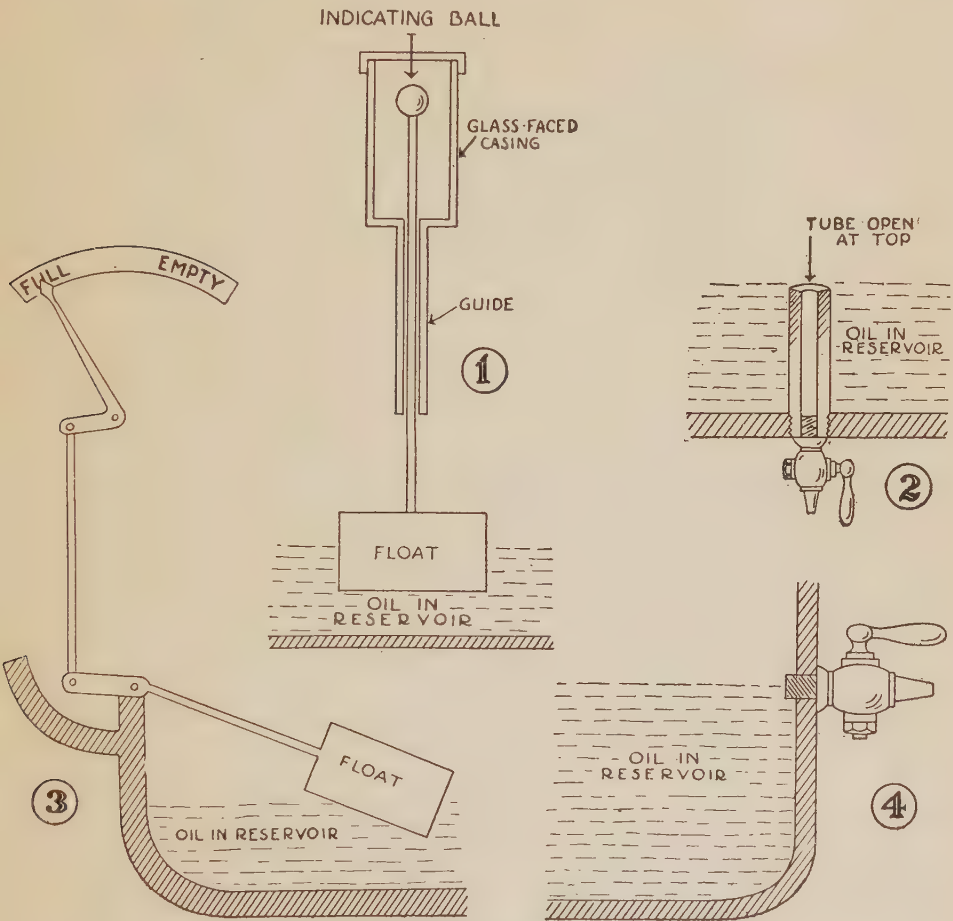
See that the supply of oil is right. In practically all cases this is made a simple matter. Oil gauges are fitted to some engines to show the level, and the instruction book indicates at what point the indicator should stand. In some cases there is a pet-cock which is left open when the oil reservoir is filled, and when oil runs out of the cock the filling should be stopped. Simply make sure that you are using the right quantity of oil.

Using the right kind of oil is a matter of knowing what you should have and getting it.

This does not mean necessarily that only one brand of oil should be

used. There are many good brands on the market. If you cannot get the brand recommended by the maker of your engine, find out what oil of the brand you can get is recommended by the oil manufacturer for your engine.

If pistons and cylinder walls are worn the fact will be made apparent by loss of compression. This, however, is by no means the only cause



HOW MUCH OIL HAVE YOU?

The various types of indicators to show the height of the oil in the engine reservoir. (1) Straight ball and float type. (2) Tube and pet cock system. (3) Float and indicator type. (4) Horizontal pet cock type.

of weak compression. For details on this head, see Chapter 3 on Pistons and Cylinders, and do not jump at the conclusion that there is wear there because of poor compression. This is important. If, however, smoking is due to this cause the fitting of new pistons and the reboring of the cylinders may be necessary. In many cases the fitting

of new piston rings will be sufficient. All of this is covered in detail in Chapter III.

Effects of Poor Lubrication.

The most serious effect of poor lubrication is abnormal wear, and this is found in its worst form in the cutting or scoring of the cylinder walls. This means that grooves or scratches are cut which may be deep enough to allow leakage from the combustion chamber into the crankcase.

Leakage into the crankcase is followed by several evils. The compression is not held, and the engine loses more or less power, according to the depth of the scoring. Oil works up in excessive quantities and burns in the combustion chamber, forming a deposit which in time bakes very hard. Particles of this deposit are heated by the burning charges and, remaining hot until the fresh gas is admitted, fires it prematurely and causes pre-ignition, which means further loss of power and an annoying knock.

In extreme cases the engine may continue to run after the ignition switch has been opened, or turned off, the incandescent carbon forming a sort of ignition system. This does not happen unless the engine is very badly carbonized. Closing the throttle will stop it.

Insufficient lubrication will cause the bearings to wear with abnormal rapidity. A serious shortage of oil will result in the setting up of so much friction that the bearings will heat, destroy the last vestiges of oil and cut themselves badly. Finally, if the bearings are reasonably closely fitted, they will seize or grip tightly.

Effects of Seizing.

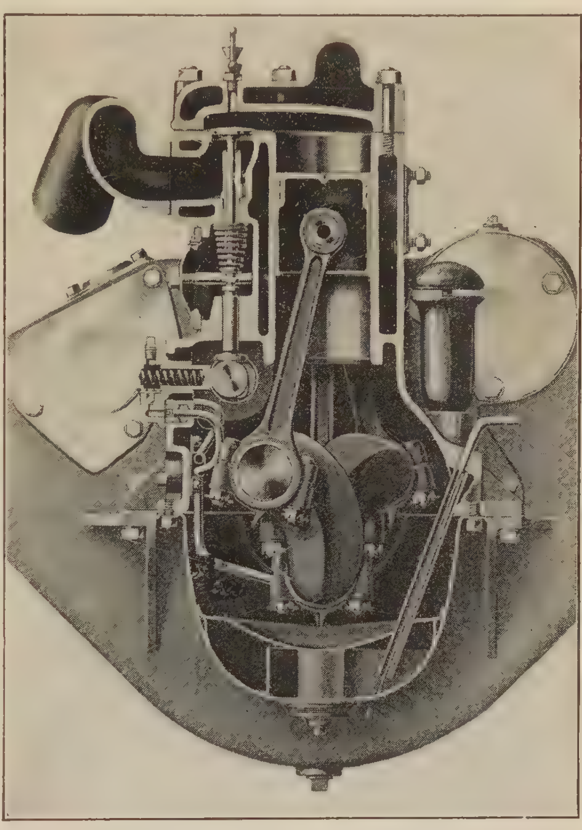
In an extreme case the seizing of bearings may wreck the engine. A big-end bearing—the bearing of the lower end of the connecting-rod on the crankpin—may seize so hard that the connecting-rod will be bent or broken. The broken rod may thrash around and punch holes in the crankcase, or bend the crankshaft, or shoot the piston upward with such force as to smash it and perhaps crack the cylinder head. The piston may fall into the crankcase and cause great damage. In fact, almost anything may happen.

If the bearings are of bronze, seizing, if it does nothing worse, is likely to cut or score both the bronze of the bearing and the steel of the crankpin, so that a repair job will include the removal of the crankshaft and the refinishing of the crankpins in the lathe in addition to the fitting of new bearings. If the bearings are lined with babbitt the heat will melt the soft metal and let it run out. The crankpin may escape

damage if the engine does not continue to run after the bearing has burned out.

This is simply to give an idea of the seriousness of improper or insufficient lubrication. Bearings and their care are fully covered in Chapter 2.

When there is leakage past the piston there is not only a working up of oil, but a downward seepage of gasoline into the crankcase. The lighter part of the gasoline evaporates and passes out through the breather but the heavier part, mostly kerosene, condenses and mixes with the oil and thins it out until, in time, it becomes practically useless as a lubricant. This is particularly true of the commercial gasoline that is everywhere supplied. The kerosene has been increasing in proportion until now (1919) it forms about 30 per cent. of the total. So it does not take long for sufficient kerosene to collect in the crankcase to seriously affect the oil. The time required will of course vary with the amount of running done, and the condition of the pistons and cylinders, but even with the pistons and cylinders in good condition kerosene may and often will work down.



CROSS-SECTIONAL VIEW OF A TYPICAL GASOLINE ENGINE

The operation of the lubricating system may be easily followed by noting the oil reservoir and sump in the bottom into which the connecting rod scoop is about to dip, the cam-operated oil pump at the left, in the center, and the supply and discharge pipes which connect this with the sump and the rest of the system.

Necessity for Changing Oil.

The oil in the crankcase or reservoir should be changed at fairly frequent intervals. It is impossible to give a rule for this because the requirements of different engines vary greatly. The safe thing is to

change oil at least as often as called for by the car builder's instructions. It is well to drain out the old oil in the evening, letting the drain-cock stand open all night and flushing out the residue with kerosene, being careful to let all the kerosene drain out.

The reasons back of this oil changing are important. Oil naturally deteriorates because of the heat, which sets up chemical changes. Then there is the admixture of kerosene already referred to. Equally bad is the accumulation of particles of metal from all the wearing surfaces, and added to this is a certain amount of dust which inevitably works in. Bear in mind that all the solid matter that gets into the crankcase and the oil stays in and gradually gets the oil into a worse and worse condition, forming a mixture that is very hard on wearing surfaces, cutting them much as emery would cut. Hard particles of carbon also get in and make matters worse.

Thus it will be seen that simply adding sufficient oil to keep the level at the proper point is altogether insufficient. The solid matter remains and keeps up its deadly work. It is well to reiterate that economy in oil is paid for at the price of engine life. Change often and save in the long run.

Oil should be changed more frequently in a new engine than in one that has been running long enough to "find itself" or get worked down to a normal running condition. New bearing surfaces yield more particles of metal than surfaces that have been worked in for a while. Then there are unavoidably some particles left in the engine in the factory.

No matter how well the engine is equipped with straining devices all this dust will go everywhere with the oil. It is much too fine to be kept out by strainers. The strainers will take care of anything that is likely to clog the pipes or the pump, where these are used, but not the fine, cutting dust.

Types of Lubricating Systems.

The simplest of all lubricating systems, and the basis of the systems in common use, is the splash system. Oil is carried in the bottom of the crankcase and the lower ends of the connecting-rods dip into it. Revolving so rapidly, they throw the oil to every part of the engine. As a matter of fact "splash" is not quite the proper word. The oil is thrown into a fine spray, and in this form readily penetrates everywhere.

The usual form of splash lubrication is the constant level type. There is a trough directly under each connecting-rod, and when the trough is full the rod dips to the proper depth. Below the row of troughs, in the very bottom of the engine, is an oil reservoir or sub-

base. A pump driven by the engine draws from the reservoir and delivers it in a steady stream to the troughs, keeping them always supplied. The pump delivers much more than enough oil, and the surplus immediately drains off and runs back into the reservoir. Thus the oil is always circulating and there always is enough in the troughs as long as there is oil for the pump to pick up. Often the oil is pumped first to the gears at the front of the engine which drive the camshaft,

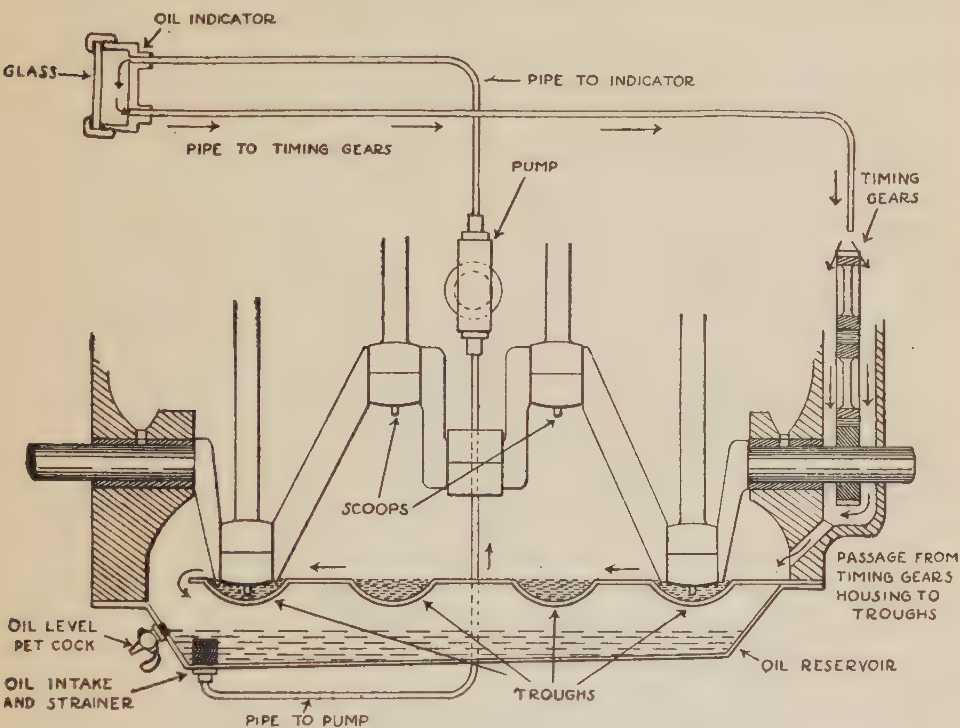


DIAGRAM OF THE CIRCULATING SPLASH OILING SYSTEM

The course of the oil is indicated by the short arrows. If these are followed closely it will be seen that each vital part of the engine is lubricated over and over again by the same oil. The oil, however, wears and loses its lubricating quality, and for this reason it must be renewed at frequent intervals.

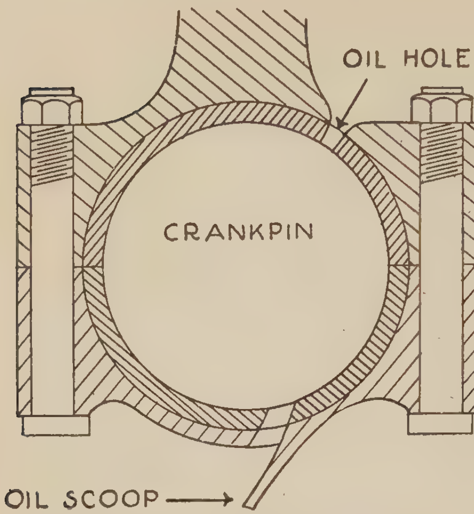
magneto shaft and other auxiliaries, keeping the gears flooded and then running to the troughs. The gears are of course in an oil-tight case.

Large oil-holes are provided leading into the bearings, so that the sprayed oil collects and runs in copiously. The lower ends of the connecting-rods have little scoop-shaped projections opening into holes in the lower bearing caps, so that the crankpins are assured of plenty of oil, and at the same time the spoons help throw the oil around.

The chief reason for using a separate trough for each connecting-rod is to prevent the oil from running to one end of the crankcase on

a grade and so giving one end of the engine too much oil and the other end none at all.

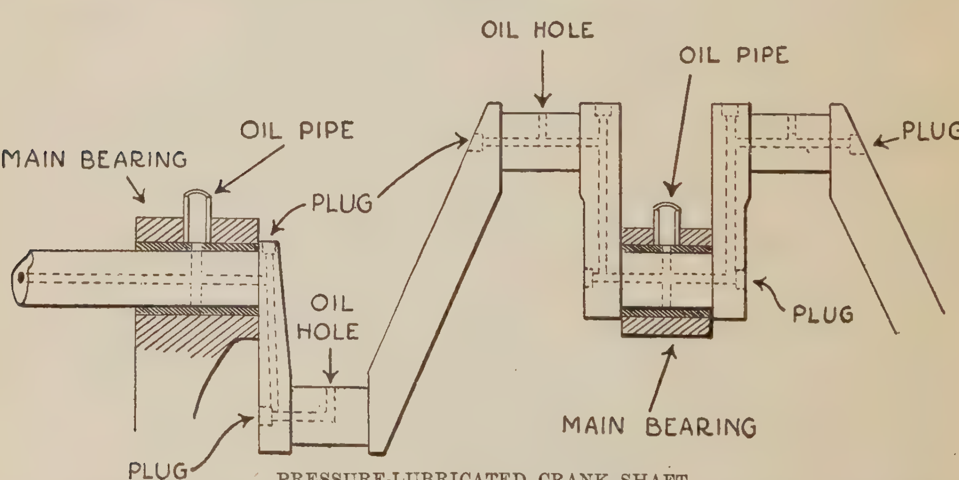
Keeping the oil constantly in circulation tends to keep it cool and prevent the thinning resulting from too high a temperature. The oil from the hotter parts of the engine eventually drains back to the cool sub-base and its temperature is considerably reduced.



THE CRANKPIN AND ITS OIL SCOOP

As the crank shaft travels downward the projecting lip of the scoop dips into the oil and the lubricant is thrown into the opening. The rotation of the crankpin carries this to all parts of the bearing. The upper bearing surface is lubricated from the splash which reaches the oil in the upper half.

The oiling system of the Ford, like many other features of that machine, is peculiar to itself. It is a constant level splash system, with no pump, however, and no reservoir under the engine. Troughs are cast directly in the bottom of the crankcase and the oil drains back to the bottom of the housing which encloses the flywheel, magneto and transmission. The oil is picked up by the flywheel from the bottom of the housing and is splashed into the funnel-shaped end of a pipe which leads forward to the camshaft gears at the extreme front end of the engine, whence it drains back to the troughs and ultimately to the flywheel housing again.



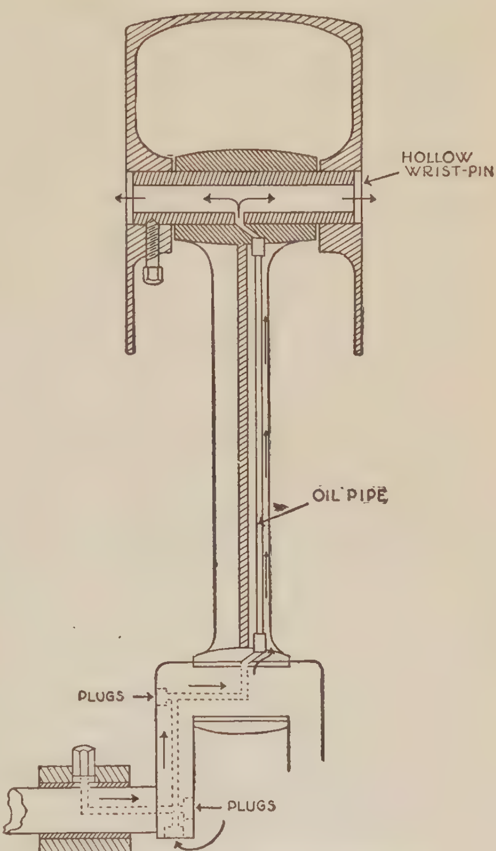
PRESSURE-LUBRICATED CRANK SHAFT

The crank shaft is drilled as indicated by the dotted line and the unused openings are then plugged as shown. The oil can then be forced through the hollow portion of the crankshaft only to those bearings which are to be lubricated by the oil holes.

In the combination force feed and splash system oil is forced by a pump to the main bearings of the crankshaft and sometimes also to the lower bearings of the connecting-rods. A surplus of oil is pumped and the oil running out of the bearings drains into the splash troughs, whence it is sprayed to the other parts, including cylinder walls, cams and so on.

Where the oil is pumped only to the crankshaft bearings—usually called the main bearings—it is necessary only to lead the oil through pipes or passages to holes in the bearing housings. Where the connecting-rod big ends are included in the force-feed system the crankshaft is drilled lengthwise and radial holes are drilled to connect the longitudinal passages with the bearings and the pump supply. The holes in the crankshaft which take the oil from the supply pipes, and the supply pipe openings, come together in each revolution.

Occasionally the force feed system is extended to the piston-pins or wrist-pins. This necessitates running pipes up from the lower connecting-rod bearings to the wrist-pins. Thence it is easy to lead the oil through the wrist-pins to the cylinder walls. When all parts are oiled by force feed it is called a full force-feed system. No dip-troughs are used, the oil running from the bearings returning to the oil reservoir.

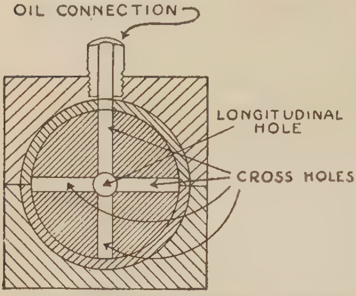


PRESSURE-LUBRICATED WRIST PIN BEARING

A drilled crank shaft communicates its oil pressure to the pipe connected with the crankpin bearing and extending up the connecting rod to the hollow wrist pin. The oil then travels downward and lubricates the cylinder walls.

In force feed systems the oil is under pressure which sometimes is considerable. The pressure increases with the speed of the engine, so that the flow of oil is automatically proportioned to the requirements. Means are provided for regulating the pressure, mainly to prevent the delivery of too much oil to the cylinder walls. Usually

part of the oil is diverted and instead of going to the feed passages returns directly to the oil reservoir. A relief-valve, or safety-valve, opens automatically should the pressure exceed a predetermined maximum. A gauge on the instrument board shows the pressure and also serves to indicate that the system is working.



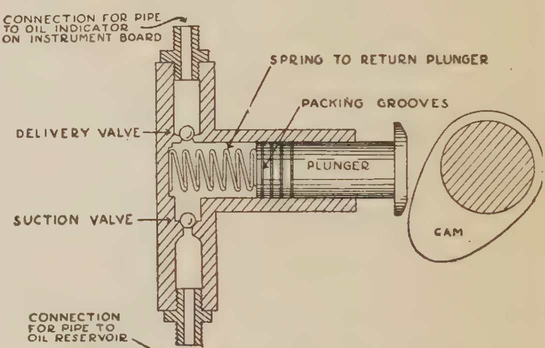
PRESSURE-FED CRANK SHAFT

The oil is fed through the central hole and then forced radially through the four openings, thus lubricating all parts of the bearing surfaces.

A gauge or indicator is commonly used with constant level splash systems to show that the oil is flowing. The simplest type, and one often used, is merely a little chamber on the instrument board with the delivery pipe from the pump leading into it and the feed pipe leading out. A glass in the front gives a view of the flowing oil.

Types of Oil Pumps.

The pumps used for circulating oil are gear pumps, plunger pumps and vane or centrifugal pumps, the latter, however, being in the great minority. The gear pump is simply a pair of ordinary gears closely fitted into a casing with their teeth accurately meshed. Suction takes place on one side of the point where the gears mesh and delivery on the opposite side, the gear teeth carrying the oil around. The plunger pump is a small piston and cylinder affair with ball check valves; the plunger is driven either by a cam or an eccentric, usually the former. The vane vamp has a set of revolving paddles or vanes in a casing and is similar to the vane water pump, but smaller.



PLUNGER OIL PUMP

The rotation of the cam forces the plunger in, while the spring furnishes the power for the return. This back-and-forth motion pumps the oil at the necessary pressure from the reservoir to the indicator and circulating system. The ball checks are automatic in their operation.

Cleaning Lubricating Systems.

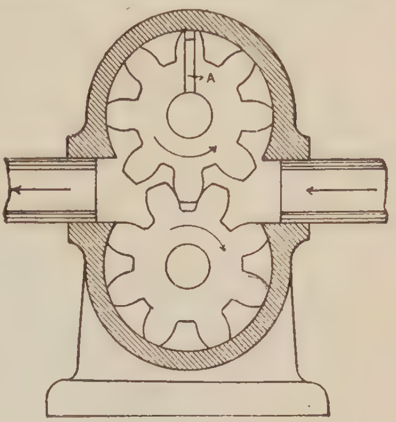
Foreign matter naturally collects in the bottom of the oil reservoir and lighter particles are caught by the oil strainers. Therefore it is ordinarily sufficient to flush out the bottom of the oil reservoir, or the bottom of the crankcase, and the oil troughs, with kerosene, and to

thoroughly clean the strainers by sloshing them in kerosene. In many cars the oil pump and strainer can be taken out with little difficulty for cleaning. A thorough flushing with kerosene, however, usually results in thorough cleaning.

As has been pointed out, it is a good thing to let the old oil drain out of the reservoir over night and to flush out with kerosene in the morning. If the kerosene comes out very heavily charged with foreign matter a second flushing should be resorted to, and even a third, if there still seems a need for it.

After a car has been driven about 500 or 600 miles the lubrication system should be thoroughly washed out.

To wash out, drain the reservoir thoroughly while the engine is hot. Fill up to the normal oil level with a mixture of three parts of kerosene to ONE PART OF THE USUAL LUBRICATING OIL. Start the engine and run it for about a minute at normal road speed. Drain out the mixture, clean the screen and the oil pan and fill up with oil in the usual way.



GEAR PUMP

The intermeshed teeth fit perfectly and produce a suction and delivery action on the oil. If the oil reservoir becomes empty this type of pump may require "priming."

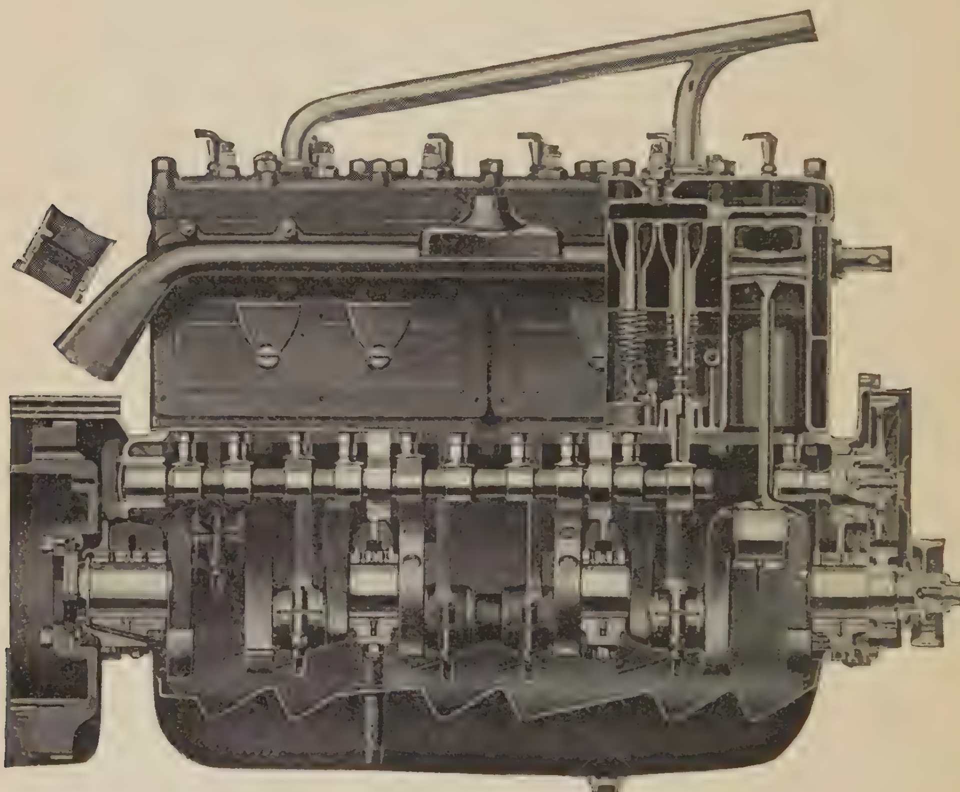
If for any reason the engine oil becomes abnormally fouled it would be well to wash out as described more frequently. Watch the oil. The condition of the lubricating oil drained from the reservoir in the ordinary way will be a guide to the cleaning needed.

In a lubricating system in which a pressure relief valve is used this valve should be cleaned occasionally to ensure its proper working. See that there is no dirt to interfere with the free movement of the spring and the proper seating of the valve. Do not change the adjustment; this is set at the factory and should not be altered except by an expert. In cleaning the relief valve, or overflow valve, be careful that no thread or lint from the cloth used gets in.

Pressure System Points.

Some cars with pressure lubricating system run normally with higher pressures than others. Do not, therefore, assume that your car's pressure is too high or too low because it differs from the pressure of some other car. An average pressure is five or six pounds when the car is running 10 or 12 miles an hour. If running on a low gear, with the engine speeded up, the pressure will of course increase, as it

rises with the speed of the engine, and not with the speed of the car. In some cases there is a connection between the throttle and the oil pump or a tilting trough, so that the wider the throttle is opened the greater the supply of oil becomes. This connection is adjustable so that the needs of the individual engine can be accurately met under all conditions. Some cars use a very much higher pressure than the



THE HEART OF THE LUBRICATING SYSTEM

A sectional view showing the inside of the crank case of a six cylinder engine. The four main crank shaft bearings and the six connecting rod bearings are plainly shown. In addition, each cam and roller as well as the individual push rods must receive their share of lubrication. The wavy white line extending close to the bottom of the crank case indicates the individual oil compartments into which each connecting rod scoop dips.

average. Find out what is the normal pressure for your car, and see that it is maintained.

Pressure will vary in a given car and at a given speed even if everything is normal. For instance, when the engine is still cool the oil will be comparatively cool and thick, and this will run the pressure up somewhat; it will drop to normal when the normal working temperature has been reached.

Oil that has been used for some time becomes thinner, as has been

pointed out, and this brings pressure down. In fact, the oil pressure gauge is a fairly reliable indicator of the condition of the oil in this respect. Running the engine continuously on too rich a mixture will tend to thin the oil through the condensation of the kerosene in the gasoline and its seepage into the crankcase, and this will show up in the reduced pressure on the gauge.

If the pressure gauge does not indicate pressure when the car gets up to a speed of ten miles an hour or thereabouts, do not continue to run it. The most likely cause, if the oil is reasonably fresh, is that the pump requires priming; that is, it must be filled with oil to enable it to suck. Disconnect the pipe immediately over the pump and pour in all the oil that can be put in with an oil gun. Be careful to make the joint tight when connecting up again. Plunger pumps in good condition do not require priming, but gear pumps, which are used more than any other type, are not as strong on suction, and when they run dry will sometimes need priming before they will start. In this respect they are much like the old-fashioned country pump which had to have water poured down its barrel before it would go to work.

Before assuming that the pump is at fault make sure that the oil level is right, that the oil gauge is not sticking and that the oil is not too thin.

Cold Weather Points.

In winter condensed moisture on the inside of the engine is apt to mix with the lubricating oil to some extent. If there is considerable water the churning of the connecting-rods may cause it to form a sort of emulsion with the oil; this is a thick mixture which may prevent the pump from working. Or the water may freeze where it naturally collects in the bottom of the reservoir and thus block the pump.

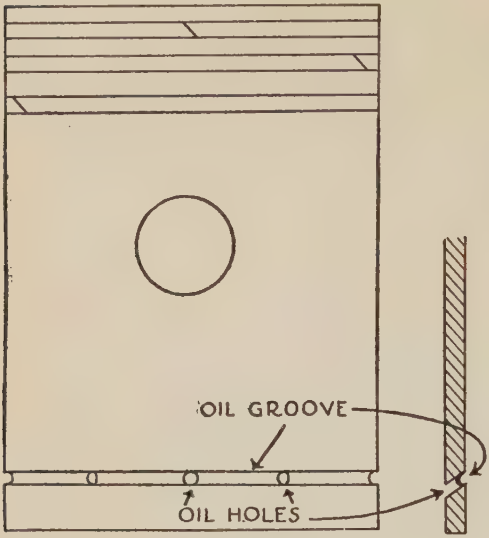
For these reasons it is well to change oil oftener in winter than in summer, in proportion to the amount of running done. If the engine is frequently warmed up and cooled down, as by a succession of short trips, the condensation of moisture will be greater than for the same mileage in a continuous run.

Water, being heavier than oil, tends to sink to the bottom and will do so unless made to mix with the oil by the churning of the rods, as described. As the pump draws from low down in the reservoir it is likely to get charged with water, and this may freeze in the pump and cause it to smash when the engine is next started up.

Drain the oil frequently in winter, and drain it when the engine is hot. Cold oil will not flow freely, and will not carry out all of the dirt with it.

Winter and Summer Oils.

In cold weather it is usual to change to a winter oil, which is of lighter body than summer oil. In some cars this is not considered necessary. Follow the maker's instructions.



STOPPING A SMOKING CYLINDER

The oil groove cut in the bottom of the piston serves to scrape the excess lubricant from the cylinder walls. The holes allow all the unused oil to drain back into the crank case.

Drilled and Grooved Pistons.

Some pistons are provided with grooves, usually below the wrist-pin, to collect surplus oil from the cylinder walls. Holes drilled through to the inside of the piston from the bottom of the groove carry such oil back to the crank-case. More often the pistons have plain oil grooves which act as little oil reservoirs, picking up oil where there is a surplus and carrying it around to points where the supply is less copious.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER I

What is the object of lubrication.

What kind of oil should be used in the engine.

What are the causes of engine smoking.

How smoking can be stopped.

What may be the effects of poor lubrication.

What is meant by the "seizing" of a bearing.

What may be the effects of seizing.

Why should crankcase oil be changed.

How too rich a mixture affects lubrication.

How the engine is affected if the oil is not changed.

What is meant by splash lubrication.

What is constant level splash.

How oil is kept in circulation.

How circulation benefits the oil.

What is meant by force feed.

How a lubrication system works where there is no splash.

What prevents excessive pressure in a force feed system.

How the driver knows whether his oil is flowing or not.

What types of pumps are used for circulating oil.

What is the method of thoroughly washing out a lubricating system.

What is the average pressure in a force feed system.

What causes pressure to vary while the car is running.

How oil temperature affects pressure.

What is the effect of oil on pressure.

What should be done when the pump does not deliver oil.

How water gets into the oil in winter.

What effects may follow an accumulation of water.

CHAPTER II

BEARINGS AND THEIR ADJUSTMENT

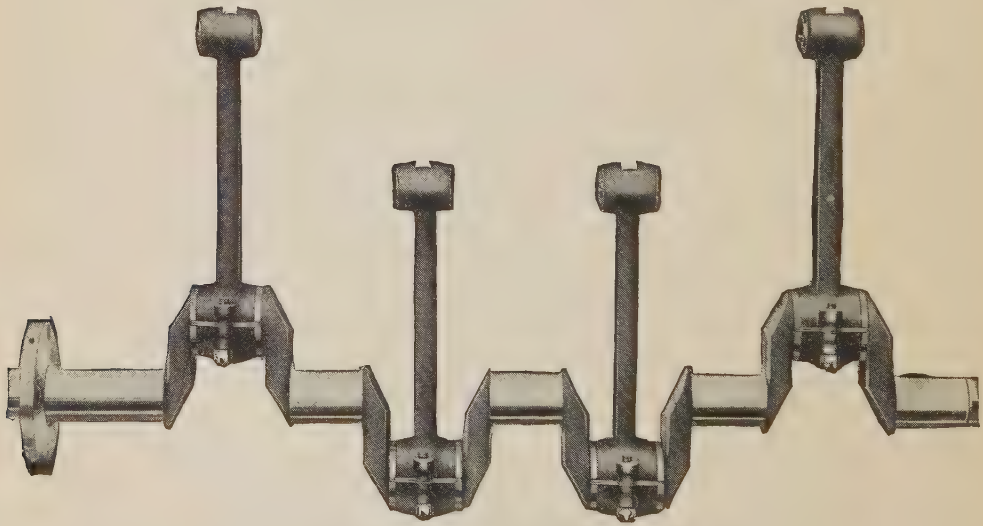
Why Bearings are Important.

The bearings are subjected to greater strains and to more rapid wear than any other part of the engine. This is unavoidable because the space available for bearings is none too large at best, and the smaller the bearing surface the more rapid the wear, other things being equal. Bearings are made as large as it is practicable to make them, they are made of the best possible materials, they are provided with means for adequate lubrication and, in most cases, they can be adjusted. Having done this, the manufacturer has gone as far as he can, and the rest is up to the man who uses the car.

The user must see that the lubrication is attended to as it should be and that adjustments are made when required. If these two points are given reasonable attention bearing trouble will be rare.

Bearings, Journals and Shafts.

Properly speaking, the bearing is the smooth, carefully-finished and fitted hole in which a shaft runs. The part of the shaft that turns in



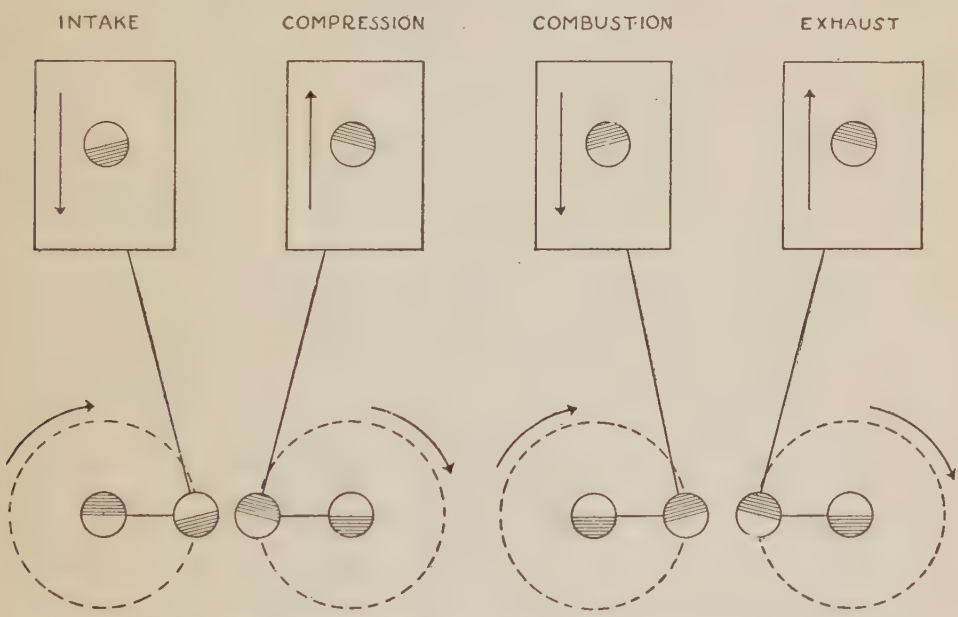
CRANK-SHAFT AND ITS CONNECTING-ROD BEARINGS

The smooth surfaces between the crank-case edge are the journals which fit in the main bearings. The connecting-rod bearing is sometimes known as the "big end" where it encloses the journal of each crank-pin. The upper or smaller end of the connecting rod is known as the wrist pin or piston pin bearing.

the bearing is called the journal. The crankpin, for instance, is all journal, for there is no part of it that is not in the bearing. A very small shaft is usually called a spindle. The main bearings are the bearings in which the crankshaft turns. The connecting-rod big-end bearings, or the crankpin bearings, are the bearings at the lower or big ends of the connecting-rods. The wrist-pin bearings are the bearings in which the pins connecting the upper ends of the connecting-rods with the pistons turn—or rather oscillate, for there is only a small part of a complete turn. Other bearings are clearly designated by their ordinary names, such as camshaft bearings, pump-shaft bearings and so on. All are made in a variety of forms, which will be taken up later.

How Bearings Wear.

Bearings are made of materials which usually wear more easily than the journals they carry. The reason for this is that it is much



THE DISTRIBUTION OF WEAR IN THE BEARINGS

The points of pressure—and consequent wear—for each position of the piston and crank are shown by the shaded portion of the main bearing, the big end connecting rod bearing, and the wrist pin bearing.

easier and cheaper to compensate for bearing wear than journal wear. For instance, it would be a serious matter to re-surface all the journals on a crankshaft (though it sometimes has to be done) while it is comparatively cheap and simple to adjust, or even renew, all the bearings of the crankshaft or connecting-rod.

In most of the engine bearings, and in all the more important engine bearings, the wear is unequal—that is, there is more wear on one part of the bearing than another. For instance, in the main bearings the greatest force—that of the combustion stroke—is exerted downward, so that the lower part of the bearing gets the heaviest pressure. The connecting-rod big-end bearings take the thrust at the top. The wrist-pin bearings take the thrust at the bottom, if the bearing is in the connecting-rod, and at the top if the bearing is in the piston. Cam-shaft bearings wear on the sides opposite the push-rods.

On the exhaust stroke, with the piston going up, the pressure is in the same direction as on the power stroke, though of course much less. On the intake stroke the direction of strain is reversed, the piston tending to resist the downward pull, so that the strain is brought against the lower part of the big-end bearings, and so on with the other bearings.

In the case of the crankshaft bearings there is little effect from the reversal of forces. Only one stroke out of four produces a reversal. In a four-cylinder engine three pistons are exerting a downward pressure due to combustion, exhaust or compression at the same time, more than offsetting the opposite force. Thus the upper parts of the main bearings wear very slightly under normal conditions.

An additional factor in bearing wear is that the pistons, moving at high speed, must be stopped and started in the opposite direction at each stroke. On the upward strokes—exhaust and compression—the pistons work against pressure, so that the effect of the momentum of the pistons is considerably lessened, especially in the case of the compression stroke. But on the combustion stroke the bearings get the full force of the weight of the pistons and connecting-rods, plus the force of the explosion, and the resulting total pressure is very heavy. The piston is shot downward precisely as a projectile is shot out of a gun, and it has to be stopped by the crankshaft through the connecting-rod.

Effect of Loose Bearings.

When a bearing is a good close fit on its journal the wear is slight and, with good lubrication from proper oil, the fit will be maintained for a really surprising length of time. But when wear gets to the point where there is actual looseness or play, and a knock, imperceptible at first, begins to develop, the process becomes much more rapid, and *the greater the play the more rapidly more play develops.*

Remember this when the first suspicion of a knock appears and you are tempted to let it go for a while.

A bad knock will grow from a slight one very much faster than a slight knock will grow from a closely fitted bearing.

The reason is that looseness permits pounding or hammering. At each stroke the bearing is pulled up tightly against its journal on one side and a space is left on the opposite side. Then when the direction of pressure is reversed the loose side of the bearing is slammed down on the journal with a blow that may be equivalent to a blow from a heavy sledge-hammer. The bearing metal is actually pounded into itself and out at the edges, if it is a soft metal. Whether the metal is hard or soft the blow tends to force out the lubricating oil and bring the metals into actual contact, and as this occurs always and repeatedly at the same places, the surfaces are impaired. Ultimately there occurs what amounts almost to temporary adhesion of the surfaces, and shreds of metal are torn loose.

In a bronze bearing the shreds torn out will dig into the journal and cut it. Even a babbitt bearing, when loose, will not infrequently wear a crankpin out of round, so that when the bearing is tightened up it will be loose in one place and tight in another. *It is utterly impossible to keep an adjustment when the journal is even slightly out of round,* even if the surfaces are still perfectly smooth and polished.

Keep your bearings adjusted so that there never is any knock and they will not wear out of round. They will run, and run well, until the bearings are actually worn beyond further adjustment. An old bearing surface runs better than a new one. In most cases the interval between the starting of a new engine and the first bearing adjustment is considerably shorter than the interval between the first and second adjustments.

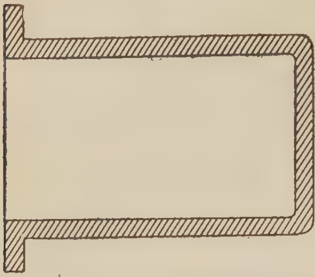
Bearing Metals.

Bearing metals are roughly divided into two classes, hard and soft. Both have advantages and disadvantages, and both are used in engines of the highest grade.

The soft metals are composed chiefly of tin and lead, with small proportions, in many cases, of copper, aluminum and other metals. They are all based on the old babbitt metal, other metals being added chiefly to give sufficient hardness to prevent crushing and squeezing out of shape under pressure. They all have the peculiarity that they acquire a glaze under friction and pressure, and with plenty of the right oil and no pounding the glaze is maintained. Once the glaze is broken by lack of oil or pounding—the equivalent of excessive pressure—disintegration is rapid.

Take a piece of soft putty and rub it gently with the finger. It

becomes glazed precisely as does babbitt, and will stand considerable friction. Press too hard and the glaze breaks, and the resulting breaking up of the surface illustrates accurately what occurs when a bearing is run under abnormal conditions.



THE "BLIND" BUSHING

This is closed at one end and is used to serve as the bearing of the end of a shaft or stud.

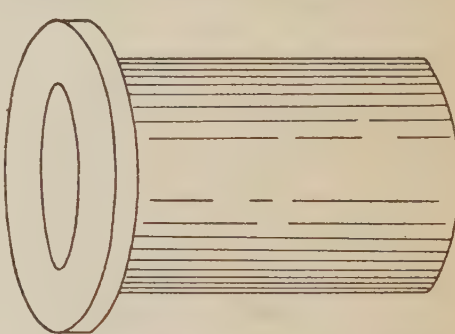
The hard metals are bronzes. Bronze is brass with a large proportion of copper. It can be made of any desired hardness—even so hard that it is almost impossible to file it. Bearing bronzes are made somewhat softer than the metal of the journals. If, however, the surface is broken and shreds are torn out, they are hard enough to cut the shaft badly, so that both bearings and journal may be spoiled.

Forms of Bearings.

A complete bearing includes a housing or box and the bearing proper or bushing. The housing is stiff and strong and supplies the strength required to resist forces, while the bushing which the housing supports simply provides a wearing surface.

Bushings are of two kinds—plain and split. The plain bushing cannot be adjusted. The split bushing can.

Plain bushings are simply short tubes, usually with rims or flanges to hold them in place. They are used chiefly in the smaller sizes where the wear is not very heavy and where it is more convenient and inexpensive to put in a new bushing when wear does occur than to provide means for adjustment.



PLAIN FLANGED BUSHING

This is to accommodate the continuation of a shaft or axle, the flange being used to hold it in its proper position.

Never allow a plain bushing to develop much wear. Put in new bushings as often as may be necessary. This, however, will not be often.

If a plain bushing is allowed to wear excessively the journal becomes worn out of round as well as getting smaller. Then when a new bushing is put in the shaft will still be loose and will soon become very loose.

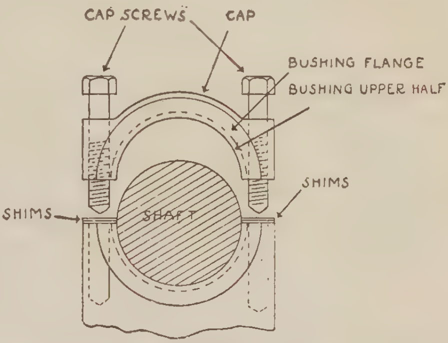
This means that the journals must be turned down in a machine shop and new bushings especially fitted. Such a job costs money and can be avoided by a little forethought—the proverbial stitch in time.

Split bushings are made in two halves held at precisely the right distance apart by the box or housing. The housing itself is in two parts also, held together by bolts. Where one part of the housing is formed in a large part of the engine, such as the crankcase, the other part is called the cap and is removed to remove the bushing.

Main bearings and connecting-rod big-end bearings are split and adjustable. The splits are always placed at the sides where there is practically no pressure, leaving smooth, unbroken surfaces at top and bottom to take the wear.

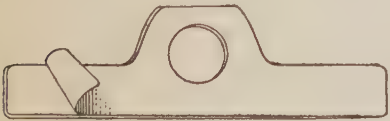
Means of Adjustment.

The standard method of adjusting split bearings is by means of shims. Shims are thin pieces of metal placed between the halves of a bearing. A number of very thin pieces are used to make up shims of the proper thickness. When the bearing is put together with the shims in place it fits the journal snugly. When wear occurs the bearing cap is removed and enough shimming taken out to let the bushing close up sufficiently to take up the wear.



ADJUSTING A CONNECTING ROD BEARING
One or more of the small strips of metal may be removed allowing the screw to bring the two parts of the bearing more closely together.

Shims are made in two principal ways. One is to use a number of separate thin leaves of metal. The other is to use special laminated shim metal, which consists of many leaves of thin brass very lightly soldered together, so that leaves can be peeled off. In either case the fineness of the adjustment is governed by the thickness of the leaves. A thousandth of an inch is a typical thickness.



A "LAMINATED" SHIM
This is composed of thin strips of metal, glued together, which may be peeled off to make the shim slightly thinner.

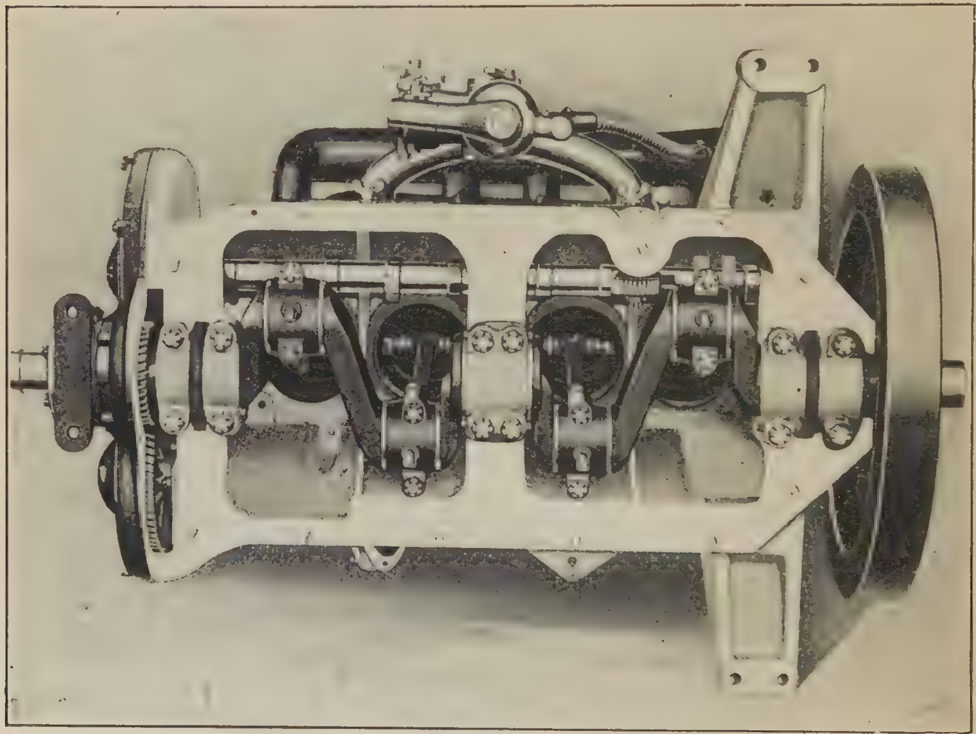
Piston-pin bearings are usually plain bushings, without means of adjustment. In some engines the piston pin is clamped in the connecting-rod and works in two bushings, one on each side, pressed into inwardly-projecting bosses in the piston. In others the pin is held tightly in the piston and the bushing is inserted in the connecting-rod as shown in the drawing on page 29. Piston-pin bushings are of bronze, with rare exceptions.

Adjusting Bearings.

As has been stated, the common method of bearing adjustment is by means of shims. In a few cases special means of adjustment are provided, such as wedges moved by screws. In such cases instruction books cover the ground thoroughly, and instructions should be followed to the letter.

Bearing adjustment may be divided into three classes—

Adjustment for slight normal wear.



REMOVE THE LOWER HALF OF THE CRANK-CASE TO REACH THE BEARINGS

The nuts, the lower half of the three main bearings, and the four connecting rod big end bearings are plainly shown. The engine need not be taken out in order to reach the connecting rod bearings for the removal of shims.

Adjustment for excessive wear.

Adjustment of new bearings.

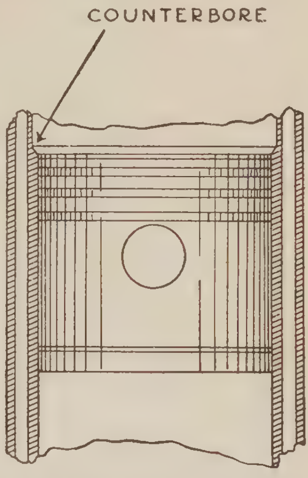
Adjustment for normal wear is the easiest and quickest of the three classes—which is another argument in favor of making adjustments before wear becomes serious.

Where only normal wear has occurred the surfaces of the bearings and the journals will be in good condition and will fit together accurately when closed up. Therefore the only requirement is that the bushings should be closed up enough to make a snug fit.

It is important, however, that when the job is done all the bearings should be as nearly as possible equal in tightness.

To adjust a set of main bearings, take off the oil pan, or the lower half of the crankcase, or expose the bearings in whatever way is provided in the particular engine in question. Remove the spark-plugs so that the engine can be turned over without resistance from compression. If the connecting-rod bearings are also to be adjusted—they usually need adjustment when the main bearings do—remove the rods from the crankpins, put the bearings caps, bushings and shims back in place and push the pistons up far enough to allow the cranks to clear the rods when turned over.

If the cylinders are counterbored—that is, if the cylinder is slightly larger in diameter just above the point reached by the top of the piston at the top of its stroke—the rings will probably catch on the shoulder so that the piston cannot be forced back. If you know the cylinders are counterbored do not push the pistons up unless you know they can be replaced from the bottom. (See Chapter 9 and study your instruction book.)



COUNTER-BORED CYLINDER
The piston in this cylinder must be replaced through the bottom in order that the shoulder, or edge formed will not catch on the piston ring.

The reason for removing the rods is to make it easier to feel the tightness of the adjusted bearings by turning the shaft over with the crank. If it is not practicable to remove the rods as described, proceed with the rods in place and the caps on the bearings loosened by loosening the bolts holding them in place. Then turn the engine over with the hand crank and see how much strength it takes to turn it, and keep this in mind.

Loosen slightly the cap bolts on all the main bearings. Do not remove them all, but take off the cap of one of the end bearings. Take out *one shim leaf from each side*. Replace the cap and tighten the bolts.

Be absolutely certain that you put the cap, shims and bolts back exactly the way they were. Reversing a cap may, and probably will throw the bearing out of line, even though it looks just the same one way as the other. Look for marks indicating which way the cap should go on. If there are no marks, make a couple of scratches to guide you.

Turn the crank, and if the shaft turns a trifle stiffly it is all right. It is impossible to tell just how stiffly it should turn, but the use of a

little common sense and intelligence will suffice. But be sure the stiffness is real and not imaginary.

If the bearing is as free as it was before, repeat the process, taking out another shim from each side, and try the crank again. Usually, however, one shim will be enough, assuming that the wear is only normal.

Do not try the tightness of a bearing with the bolts only partly tightened down. Shims "pack" and the last turn of the bolt may make a good deal of difference.

If the removal of one pair of shim leaves makes the bearing too tight it indicates either that the bearing is not sufficiently worn to require adjustment, or that the shim leaves removed should be replaced with thinner ones. The latter is a simple matter. Take a shim leaf to a hardware store and get a piece of hard-rolled brass or copper of about half the thickness and cut out a new pair of leaves of exactly the same shape and size as the old ones. This is very easily done with a pair of ordinary scissors. Be sure there are no burrs or ragged edges on the news shims. They would prevent the bearing from coming together properly.

To remove burrs, lay the new shim on a smooth board and rub the edges with emery cloth on a little block of wood. Be careful not to bend or buckle the thin metal.

If necessary, an exceedingly fine adjustment can be made by using one of the old shim leaves on one side and one of the new and thinner ones on the other. The inequality is so slight that it will make no difference in the lining up of the bearing.

When one bearing has been adjusted and found satisfactory with the bolts perfectly tight, loosen the bolts enough so that the shaft turns as freely as before the adjustment was made, and proceed with the next bearing in the same way precisely.

Never try to adjust one bearing while another is tight. You cannot tell when the new bearing is adjusted if you do.

In adjusting the connecting-rod big end bearings exactly the same principles apply.

Loosen the main bearing bolts just enough to let the shaft turn perfectly freely, but without shake or looseness. Set up the rod bearings one at a time. When one bearing is finished, remove it from the crankpin if practicable, and go on with the next. If it is impracticable to remove the rods in this way loosen the bolts, as in the main bearings. In this case the friction of the pistons must be considered. It makes it a little more difficult to feel just when the bearing has been tightened enough and a little extra care is necessary.

Taking Up Excessive Wear.

When the bearings are so worn that there is bad knocking when the engine runs the work is somewhat more difficult, if a really good job is to be made. The reason is that the bearings are likely to be somewhat pounded out of shape, so that their surfaces do not correspond accurately with the journal surfaces.

There are three courses that can be pursued.

If the bearings are not scored or cut they can be taken up precisely as has already been described. This, however, must be regarded as a temporary expedient to permit the finishing of a trip or something of the sort. A really good fit cannot be expected, and the car should be run carefully at first in case the bearings have been thrown out of alignment. A thorough job should be made at the first opportunity.

To do the job properly, if you are not something of a mechanic yourself, turn it over to a repairman who knows his business.

If you are something of a mechanic you can refit the bearings. Be prepared for a good deal of close and careful work.

In many cases it will pay to take the engine out because much time is saved in the fitting. This, however, is a point that must be determined by the ease or the difficulty of taking the engine out, and the ease or the difficulty of getting at the bearings.

Uneven Wear.

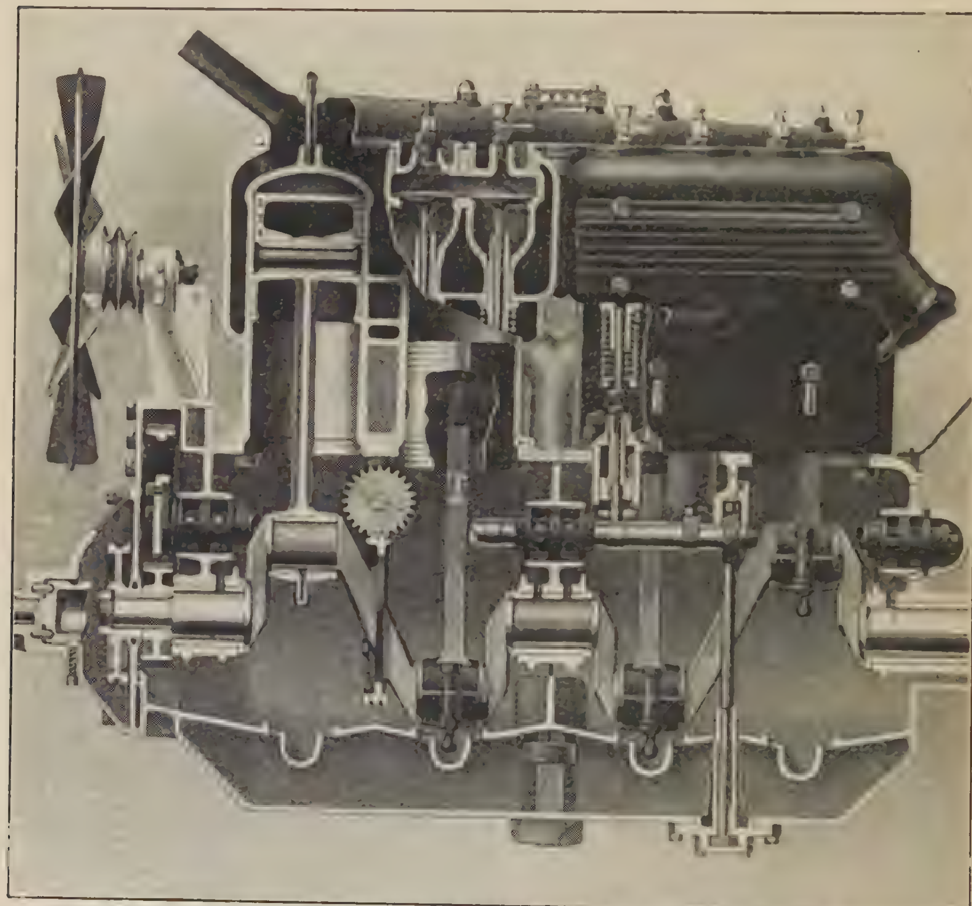
The reason why badly worn bearings should be thoroughly overhauled is that they are likely to be worn unevenly. So when the wear is simply taken up in the ordinary way one main bearing, for instance, might be a little lower than another and there would be a tendency to spring the crankshaft, and this tendency would react on the bearing and make it tight in one spot and loose in another. The result would naturally be rapid wear of the tight places and further distortion of the surfaces. In many cases the setting up of bearings in this way will cause knocking, heating and endless trouble. Some engines are more delicate than others in this respect and will knock if the bearings are the smallest degree out of alignment.

Begin by examining the bearings and journals. If the latter are scratched and scored, turn the job over to the repairman at once and let him refinish the surfaces and fit a new set of bearings.

If the journals are smooth and in good condition there is still a possibility that the repairman's help must be requisitioned. This will be in case the crankpins are worn out of round, caused by a greater pressure exerted at some portions of the surface than at others.

Testing for Wear.

To test for this, remove the crankshaft. Take one of the connecting rods and adjust the big end bearing to its crankpin so that it is a good, snug fit. The bearing should be tight enough so that when the rod is in a horizontal position it will just support itself and no more.



SIDE VIEW OF THE ARRANGEMENT OF BEARINGS IN A FOUR CYLINDER ENGINE

It is difficult to locate a loose bearing by means of the hand crank, for the three main bearings, the four big end bearings and the four wrist pin bearings will each and all make a sound if undue looseness exists.

Swing the rod in a complete circle and note carefully if it is equally tight in all positions. If the crankpin is out of round the bearing will be tighter in some places than in others, and this can readily be felt. If there is any inequality, get the pins trued up. If you can feel absolutely no difference throughout the swing of the rod the journal may be considered in fairly good shape.

This is rather a rough test and by no means as accurate as a test

made with a micrometer; but a journal that passes will give good service, providing, of course, that it is smooth and unscratched.

The main journals will wear out of round only in extreme cases; but if it is necessary to send the shaft to the shop to have the crankpins refinished the main journals should be accurately gauged and trued up if necessary. The result will be a crankshaft as good as new.

Marking.

Whether you are refitting badly worn bearings or putting in new ones, first adjust them all, as has been described. Have them perfectly clean and use no oil. Then take off the caps, take out the crankshaft and coat the journals lightly and evenly with blue marking, which can be purchased at any supply store. Good marking can be made by mixing ordinary red lead, such as is used in paint, with lubricating oil to the consistency of a thin paste. Put the crankshaft back in place, being careful to avoid rubbing it on the bearings when putting it in. Put on the caps and set up the bearings as in a final adjustment. Turn the shaft over half a dozen complete turns and take it out again. You will find that where the journals have touched the bearings there will be marks left by the blue or red stuff. The marks indicate the high spots. If very high they will probably be rubbed clean of marking and will show a dark burnished surface.

Scraping.

Cut down the high spots in all the bearings with a scraper. Where the pressure has been heaviest, take off the most.

Under no circumstances touch with the scraper the parts that show no marks.

Scrape lightly, taking care that the cuts do not go deep. Remember that the object is to eliminate all high spots and bring them to the level of the low places.

When all the bearings have been gone over in this way, wipe bearings and journals perfectly clean, put marking on the journals and put the shaft in as before, turn it again and go on scraping.

Scraping and trying should be continued until the marks show that the bearings and journals touch fairly evenly throughout their length. It is very difficult, even for an expert, to make an absolutely perfect job of scraping—that is, make journals and bearings touch all over. It is not necessary, for a very little running will wear the surfaces to a perfect fit.

Under no circumstances, however, must there be contact at one end of a bearing and not at the other.

If, after considerable scraping, it is found impossible to get contact at both ends of a bearing, it indicates that the bearing or its housing is out of true, as a mechanic would express it. This may necessitate work that is beyond the average amateur mechanic's scope. Better turn it over to a repairman.

The sides of the bearing—just above and just below the split—do not need to be as close a fit as the top and bottom. In fact, they are better left just a trifle free. Use a little extra vigor in scraping at the sides, so that if there is contact, it will be very light.

Babbitt Bearings.

Scraping babbitt bearings requires rather a delicate touch because of the softness of the metal. It is very easy to dig in too far.

A babbitt bearing does not require quite as fine a scraped finish as a bronze bearing because the softness of the metal allows it to work into shape more easily. But always there must be good contact, and equal contact, at both ends and at least two or three places in between.

Scrapers.

Better buy a good set of scrapers for the job. Scrapers can be made from old files or from tool steel, but a regular tool is the best. Take care that the curvature of the scraper is such that no corners can dig in and, on the other hand, that it will not take a gouge out of one spot. The tool should be curved just a trifle more than the bearing surface.

Scrapers can be made from old files by grinding off the teeth and grinding the ends square across for the cutting edges. It is not necessary to grind the teeth off completely except at the cutting end, though it is advisable to take off the roughness all over. A half-round file makes a fairly good bearing scraper. If it is too small at the end, break it off and grind it down.

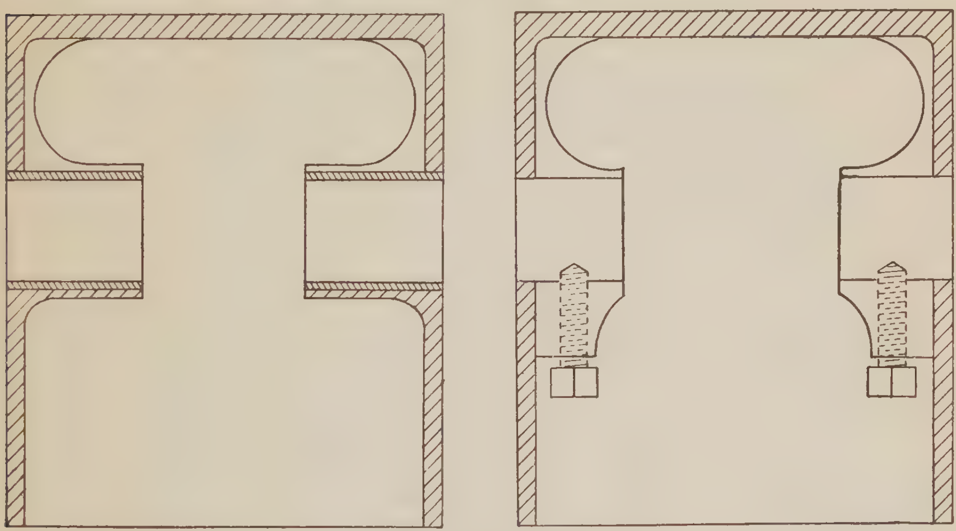
Seized Bearings.

Occasionally a bearing will seize or "freeze" and yet suffer no harm if the engine is immediately stopped, but this is the exception and not the rule. A bearing that has seized should be examined at once and put in good condition.

If the bearing has seized very suddenly and brought the engine to an abrupt stop it may be that the crankshaft will be sprung or, in the case of a seized connecting-rod bearing, that the rod will be sprung. Accurate tools, used with skill, must be used to determine this. Let a good repairman do it.

Usually the seizing of a bearing is preceded by sluggishness and lack of power in the engine, due to the great friction, and this increases rapidly until the engine stops or the bearing, if of babbitt, melts out and the engine starts pounding severely.

Watch the engine carefully for a while after bearings have been newly adjusted or new bearings put in. Also watch it in case you are doubtful about the lubrication system. A bearing that is just a little too tight often will heat up very gradually; the heating makes it tighter and the increasing tightness forces out the oil and prevents proper lubrication until finally the bearing runs dry and grips the journal hard and fast. If no harm has been done by the seizing it is necessary only to adjust the bearing properly. But make very sure that no harm has been done.



TWO TYPES OF WRIST PIN BEARINGS

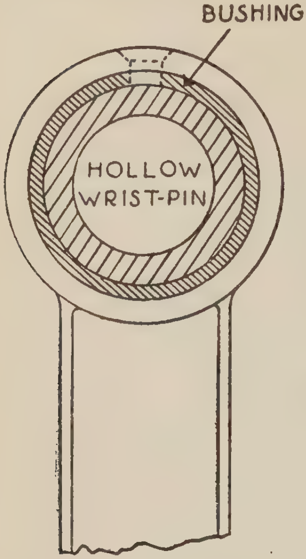
The one on the left shows the design in which the wrist pin is clamped to the connecting rod and moves in the piston bosses; and the one on the right shows the type in which the wrist pin is securely held in the piston bosses, providing for the bearing in the upper end of the connecting rod.

Wrist-pin Bearings.

When a wrist-pin bearing is worn it is replaced. Bronze bushings are pressed into the piston bosses or into the eye of the connecting-rod, according to whether the pin is stationary in the rod or in the piston. The pins are made of very hard steel and wear very slightly as a rule. Therefore when looseness occurs it usually is sufficient to insert new bushings. If the pins are worn, however, it is a simple matter to insert new ones, for they will be made an exact fit for the new bushings.

Removing bushings from a piston must be done with the greatest care. The pistons are of cast iron or aluminum alloy and are machined

down as thin as possible. The metal is brittle and is easily cracked or broken by blows or pressure on the sides. Unless you have had some little experience, better let the repairman do the re-bushing to avoid the risk of breaking a piston.



BEARING IN PISTON

The small screw holds the hollow wrist pin securely in the connecting rod so that the former oscillates with it in the piston bearing.

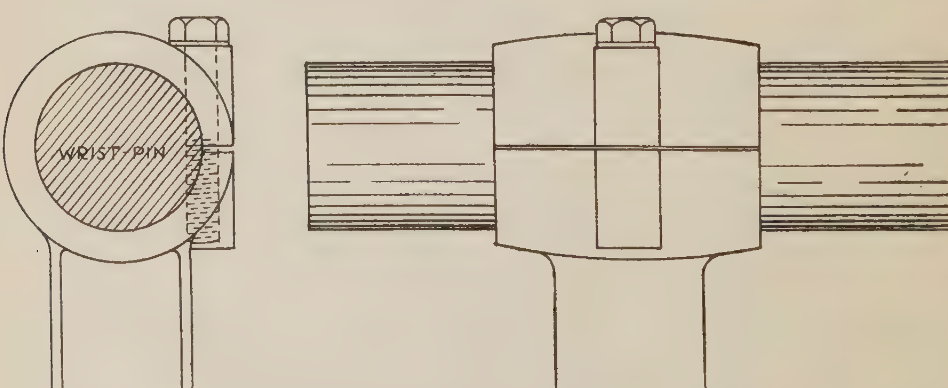
The connecting-rod is much more rugged, though it must be treated with care, of course. Sometimes a bushing is simply pressed into place in a solid eye, and sometimes the rod is split on one side and fitted with a pinching-screw or bolt. In the latter case the bushing will come out easily when the bolt is loosened.

Removing Bushings.

A pressed-in bushing can be removed by laying the piston end of the rod on a big nut, or a short piece of tube, the opening in which is large enough to allow the bushing to pass, and driving the bushing with a hammer and a round piece of wood or—if it is carefully used—a piece of round iron or steel or anything that will pass through the rod eye but not through the bushing.

Care must be taken not to burr up the rod where it rests on the nut or tube.

Putting in the new bushing has to be done very carefully, in the case of a pressed-in job, because the fit is very close. If the bushing is not started perfectly in line with the hole in the rod it is very likely to be

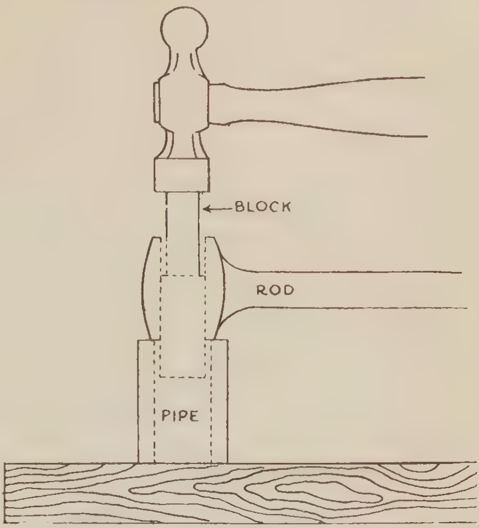


A POPULAR METHOD OF HOLDING THE WRIST PIN SECURELY IN THE CONNECTING ROD

The upper end of the connecting rod is split and is clamped together by means of a bolt. The wrist pin oscillates in the top of the piston as shown in the left hand part of the second drawing preceding.

cut by the edges of the hole and may be distorted, so that it will not allow the piston pin to pass.

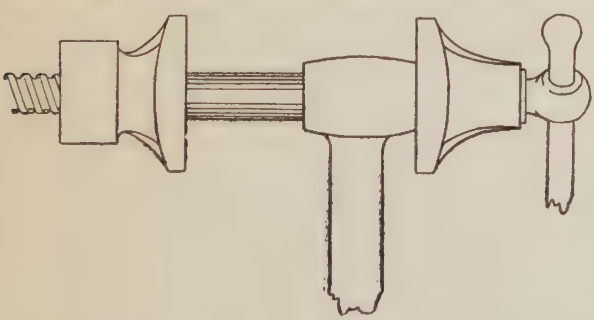
A good machinist's vise makes an excellent press for putting in these bushings. In a well-made vise the faces of the jaws are square and parallel. Start the bushing in the rod eye by hand, working it in as far as possible and, if necessary, tapping it gently with a block of wood—never with a hammer—until it lines itself with the hole. Then put rod and bushing in the vise, with the bushing end against one jaw and the rod eye against the other. Oil the bushing so that it will slip in the more easily and also to prevent rusting in place. See that the jaw faces bear squarely on both bushing and rod, and tighten up, gradually and carefully, watching to see that the edge of the hole in the rod does not dig into the bushing at any point. Keep on tightening until the bushing is all the way in.



REMOVING THE CONNECTING ROD BUSHING

Neither the bushing nor the wrist pin should ever be struck by a piece of hard metal. A block of hard wood, or a piece of copper or lead should be used to drive out the bushing.

Put pieces of sheet copper or brass between the vise jaws and the bushing and the rod so that the hard metal of the vise will not mar the softer metal of the bushing and the rod. Use pieces that are flat and straight.



THE VISE AS A PRESS

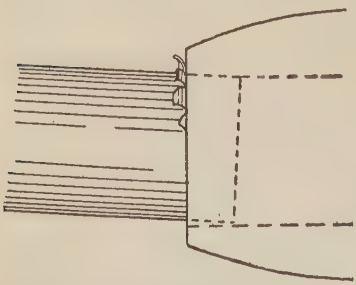
If the edges are perfectly square and the work is held properly a tremendous pressure can be safely exerted on the connecting rod and bushing when the vise is tightened.

Small Bearings.

Camshaft bearings sometimes are adjustable and sometimes are solid bushings. The same principles apply to them as to other bearings. They are not subjected to hard service in the same degree as the larger bearings, however, and are not liable to freezing or to pounding out.

Before trying to remove a solid bushing look very carefully to see

how it is held in position. Sometimes there is a flange at one end. Sometimes there is a shoulder inside the housing that the bushing butts against. Sometimes there is a screw or "Dutchman" inserted half in the bushing and half in the housing to keep the bushing from moving.

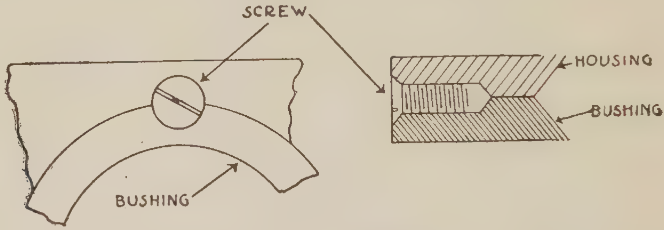


BE SURE THE BEARING STARTS STRAIGHT

Otherwise the edge of the connecting rod will cut the bushing and ruin its highly polished surface.

Removing a Solid Bushing.

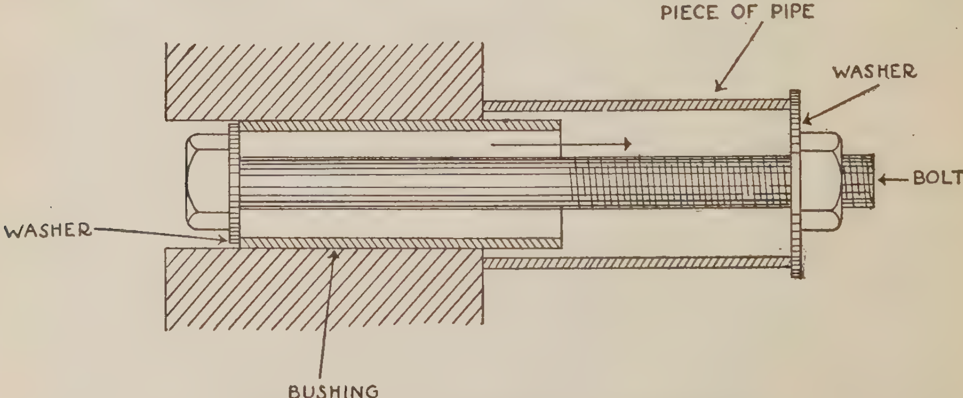
It is very much better and safer to pull or push a solid bushing out than to knock it out. A tool for pulling is very easily made —in fact, it does not need any making to speak of. Get a bolt that will easily pass through the bushing and with a head that is larger than the hole in the bushing and smaller than the outer diameter. If the head is too



A "DUTCHMAN"

This is a small screw which sticks part-way into the housing and part-way into the bushing, and prevents the latter from turning. The bushings should always be replaced or renewed with the hole in exactly the proper position so that the screw may be driven home.

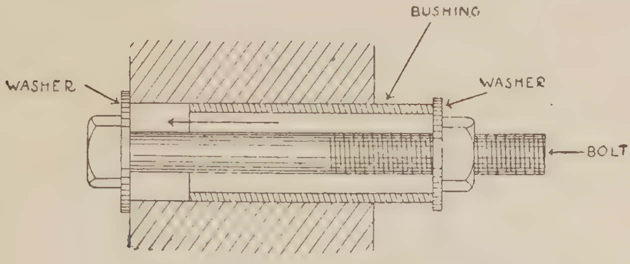
small use a washer of the right size. Put the bolt through the bushing with the threaded end pointing in the direction in which the bushing is



A HOME-MADE TOOL FOR REMOVING THE BUSHING

The parts can be found in almost any garage or machine shop and the work which it does is almost as effective as a specially-constructed press.

to move. Slip over the projecting end of the bolt a piece of pipe large enough for the bushing to pass through it, letting the inner end of the pipe butt against the housing around the bushing. Put the nut on the bolt with a washer to keep it from going into the pipe, make sure that everything is clear, and screw the nut on with a wrench, applying

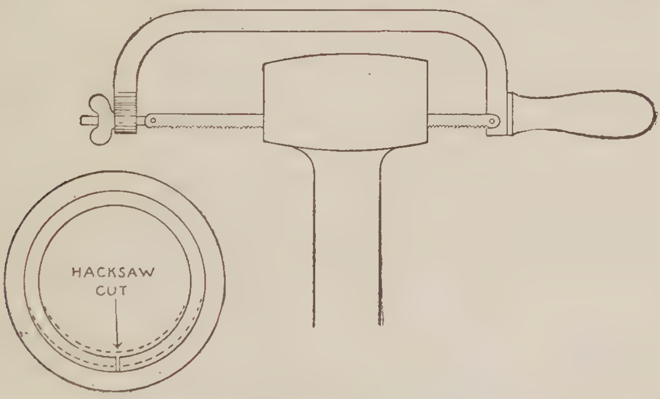


FORCING THE BUSHING HOME

The same device as illustrated in the preceding cut can be reversed and by the use of a larger washer made to press the bushing back into place.

pressure and gradually pulling the bushing out. If the bushing seems very obstinate look to see if there is anything holding it.

A bushing can be put in by the same process reversed. Put a big washer on the head of the bolt so it will not come through the housing and another washer over the end of the bushing and screw up.



REMOVING THE BUSHING WITH A HACK-SAW

A thin cut from a hack-saw blade will allow a bushing to be contracted sufficiently to be driven out without damage by the methods previously described.

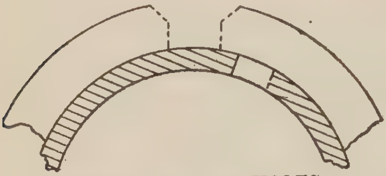
In starting the bushing the same care must be observed as in starting the connecting-rod bushing. The same tool can be used for both jobs if a good vise is not at hand for the connecting-rod work.

Be careful to get the new bushing in exactly the same position as the old one. If the bushing goes in too far the shaft may jam or

it may not go into place. If it does not go far enough there will be play endwise.

Removing a Frozen Bushing.

Sometimes a bushing will stick in place, through the rusting of the housing or for some other reason, and cannot be moved with the tools at hand. Probably it could be done by heavy blows with a hammer, but this is a dangerous business. In the case of a connecting-rod bushing make a hack-saw cut along the length of the bushing from the inside, removing the blade from the saw frame, passing it through the bushing and putting it on the frame again. Work carefully, so as to avoid cutting the housing; a scratch or two will do no harm, however. The cut will allow the bushing to be closed in a little by a few taps with a hammer and drift and it will come out easily. Where a saw cannot be passed through a cut can be made with a file.



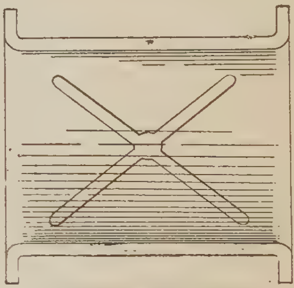
WATCH THE OIL HOLES

If the oil hole in the bushing does not register with that in the bearing no lubricant can reach the journal and the bushing, and possibly the bearing will need to be removed almost as soon as the engine is operated.

Oil Holes and Grooves.

When inserting bushings *see that the oil holes come in the right place, so that they register with the holes in the housing.* Otherwise the bearing will get no oil.

Sometimes oil holes are drilled in bushings after they have been inserted in the housing, and a new bushing would have no oil hole. Put the bushing in and drill through the hole in the housing. If there are oil grooves, make sure that the hole connects with the grooves, which are necessary to distribute the oil all over the bearing surfaces. This is important, for an oil-hole that does not connect with the oil grooves is not of much use. In small bushings, however, oil grooves are often omitted as unnecessary. But look out for clear oil-holes.



LUBRICATING THE BUSHING

Many connecting rod bearings are provided with grooves or cuts in the surface, which connect with the oil hole. These help to distribute the lubricant over the full width of the bearing.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER II

Why bearings are important.

What bearings, journals, shafts and spindles are.

How and why bearings wear.

What happens when bearings get loose.

How knocks grow.

Why frequent adjustment is economical.

What metals are used for bearings, and why.

What forms bearings are commonly made in.

The difference between adjustable and non-adjustable bearings.

How bearings are adjusted for normal wear.

How bearings are adjusted for abnormal wear.

How new bearings are fitted.

How bearings are scraped in.

How to tell when a bearing is properly adjusted.

What shims are and how they are used.

How to make shims.

Why crankpins wear out of round.

How bearings seize, and what to do with them when they do.

How solid bushings are removed and replaced.

How to make a tool for removing and replacing bushings.

How to remove a stuck bushing.

The importance of getting oil holes where they belong.

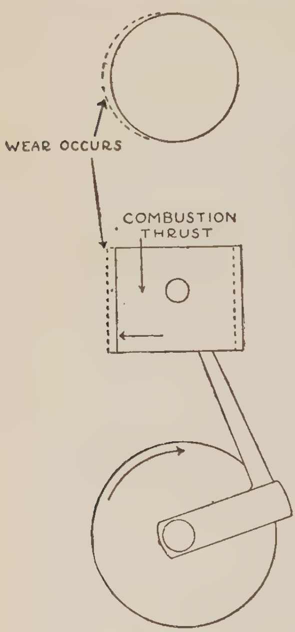
CHAPTER III

CYLINDERS AND PISTONS

Why Good Condition is Essential.

Cylinders and pistons lie at the root of the power of the gasoline engine, and upon their good condition depends the possible amount of power obtainable. No degree of perfection in other parts will avail if pistons and cylinders are not right.

The greatest possible care should be taken to keep cylinders and pistons in good condition because they offer less opportunity for adjustment than any other part of the engine. The only real adjustment is that which is provided automatically by the piston rings, which are constantly pressed against the cylinder walls and follow up normal wear without allowing leakage.



"OVALIZING"
The greater thrust at the side of the piston due to the reaction of the connecting rod during the explosion stroke tends to wear the piston slightly oval in shape.

So far as the cylinder proper is concerned—that is, the part of the cylinder that is traversed by the piston—all that can be done is to see that the proper oil is used in the proper quantities.

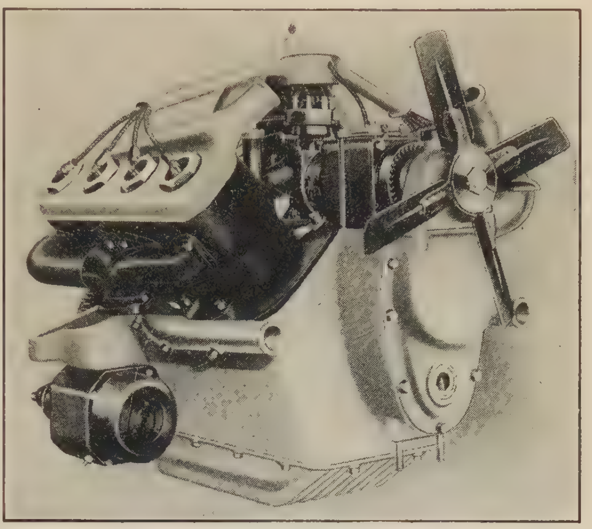
How Cylinders Wear.

While cylinder wear is naturally very slow, it unfortunately occurs chiefly at the sides. The right hand side of the cylinder gets the greatest wear because the piston is forced against it by the pressure of combustion from above and the resistance of the connecting-rod from below. So cylinders wear oval in time.

Cylinder Wear in V-type Engines.

The idea that the cylinders of V-type engines are subject to abnormal wear at the bottom because of the weight of the pistons may be classed as a superstition—an exploded notion. The wear due to this cause is negligible. In old-fashioned horizontal engines with heavy pistons there was a little extra wear due to piston weight, though not a great

deal in a well-designed engine. But in a V-type machine the pistons are so extremely light that they cause no appreciable wear in excess of that which would occur were the same cylinders to be set vertically. Further, the cylinder wall does not even carry the full weight of the piston. The cylinders are at such an angle that part of the weight is carried by the crankshaft, leaving only a portion to be carried by the cylinder.



IN THE "V" TYPE ENGINE, CYLINDERS ARE SET AT 90 OR AT 60 DEGREES

This angle, however, does not serve to increase the wear of the cylinders on the lower side. The opinion that the "V" type engines wear more rapidly than vertical engines is an exploded fallacy.

What To Do with Worn Cylinders.

When cylinders are badly worn there is no real remedy except to have them rebored and fit new pistons and rings. Reboring calls for new oversize pistons and rings because the cylinders are made slightly larger, and the old pistons and rings would be loose and leaky. It is a job for the well-equipped shop throughout. Put it off as long as possible *by being careful of your lubrication.*

Sometimes compensation can be made for slight cylinder wear by putting in new piston rings. This will be taken up later. The use of a heavier grade of oil is sometimes suggested for sealing the space between piston and cylinder; but this is a practice that is risky and is but a makeshift at best. The heavier oil does not flow as readily in the passages and bearings and inadequate lubrication may result.

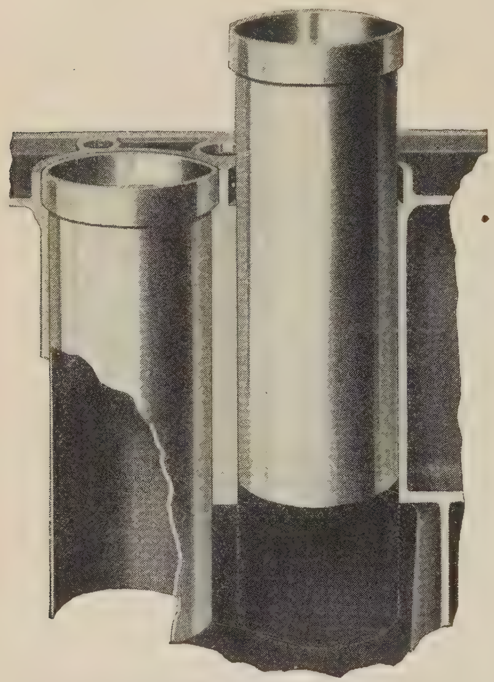
How Cylinders Become Scored.

Cylinders become scored, or deeply scratched lengthwise, from lack of lubrication, broken piston rings, projecting piston pins or piston pin bushings. A scored cylinder will leak and may leak badly enough to cause a hissing sound that can be heard. The only remedy is reboring and new pistons and rings.

If the scoring is slight only the cylinder affected need be rebored. If it is very deep it is best to have all the cylinders re-finished, as the increase in diameter may be sufficient to throw the engine out of

balance a little and cause vibration. A good deal depends upon the individual engine.

Consult a really good repairman about it. Be sure he is a good one, and accept his judgment.



IRON SLEEVE IN AN ALUMINUM ENGINE

Aluminum does not make a satisfactory wearing metal when placed in rubbing contact with another part of the same material. Many aluminum engines, therefore, are provided with iron linings or sleeves which are placed in the cylinder casting and in which the aluminum pistons move up and down.

If lack of lubrication does not directly result in scoring, it may cause the breakage of piston rings and then scoring.

What To Do When Pistons Seize.

When a well fitted piston is allowed to run without sufficient lubrication it gradually runs perfectly dry and then becomes abnormally hot and sticks fast, stopping the engine. As a rule the cylinder walls will be scored, or the pistons and rings affected, or both.

Put kerosene on the piston. It will work down and help to free the frozen surfaces. Wait for the engine to cool. Try the crank gently to free the piston. Do not allow a frozen piston to remain frozen. When it is free, give it plenty of oil.

Do not run the engine until it has been inspected if it can possibly be avoided.

It may be that little or no damage has been done, but that further running will result in scoring. It may be that a connecting-rod or the crankshaft has been sprung, in which case running may damage the whole engine.

If circumstances are such that the engine must be run, turn it over with the crank to see if it turns freely—*after it has been allowed to cool and has been thoroughly oiled*—and run very slowly and cautiously.

If the engine knocks when running this way, you are taking a big chance of doing damage that may be expensive to repair.

If it is found that the engine turns hard in one place do not try to run at all.

If the engine turns hard all the way round, despite cooling off and thorough oiling, do not try to run.

The gradual approach of piston seizing is often indicated by overheating which cannot be accounted for in any other way. When such overheating occurs, stop and try the engine with the crank. It will in all probability be found very stiff.

Oil with Gasoline.

If sufficient cylinder lubrication cannot be provided in any other way, put cylinder oil in the gasoline tank. Put in a pint of oil to every four or five gallons of gasoline. The oil will go into the cylinders, sprayed with the gasoline, and will stick to the walls, lubricating them thoroughly. In most cases no trouble whatever will follow this proceeding. In some cases it will make the engine a little harder to start. Many marine engines are lubricated in this way, no other means being provided for oiling the cylinders.

How Carbon Accumulates.

In the combustion chamber, which is that part of the cylinder which is above the highest point reached by the piston, the greatest trouble is from accumulations of so-called carbon. As a matter of fact, the deposits are a mixture of oil and gasoline residues and dust, which mingle, stick to the surfaces and, if allowed to do so, bake hard and may be exceedingly difficult to remove.

Too much lubricating oil and too rich a mixture from the carburetor cause carbon to accumulate. Excessive oil may get into the combustion chamber because of too high an oil level, or too rapid a feed of oil, according to the type of oiling system, or the use of the wrong oil. Too much oil is indicated by a bluish smoke in the exhaust. If smoke occurs the feed should be cut down or the oil level lowered until smoking stops.

If the engine is considerably worn, however, oil will work up past the piston even with the normal amount of lubrication, and it cannot be prevented except by stopping the leakage.

Oil is often blamed for carbon deposits when the real trouble is that the mixture is too rich. A very rich mixture will make a black or very dark smoke in the exhaust, quite different from the light-colored oil smoke. It takes a lot of gasoline to do this, however, and the mixture may be a good deal too rich without making any smoke. (See Chapter VII on Carburetors.)

Carbon Prevention.

Good oil in the proper quantity and a mixture not too rich will ensure a minimum of carbon. However, some carbon will be deposited.

There is no such thing as a lubricating oil that will not cause a deposit in the combustion chamber if the conditions are favorable to such a deposit. Some oils, however, will cause less deposit than others. This is one of the very good reasons why it pays to buy the best oil that can be had and to use it properly.

If carbon is allowed to accumulate undisturbed until the operation of the engine is affected it may be very difficult to remove. If, however, a little trouble is taken to clear out deposits at frequent intervals the engine will keep clean for a very long time.

There are many methods of cleaning out carbon. There are on the market numerous compounds for the purpose, some of which are good and some of which are not. You can find out by your own experience or that of others.

Removing Carbon with Kerosene.

About once a week, if the car is used a good deal, put a couple of tablespoons of kerosene into each cylinder through the relief-cock or spark plug hole while the engine is hot—just after stopping. Let the engine stand overnight. When it is started up in the morning the carbon will be blown out, the kerosene, vaporized by the heat, soaking into it and loosening it up. If the deposit is an old one the same process will help, and repeated applications will get rid of a good deal, but not all of it.

Removing Carbon with Denatured Alcohol.

One of the best carbon removers is denatured alcohol. It will often do remarkably good work and will not affect the cylinder walls, pistons or rings. It will free the piston rings if they have become gummed in their grooves and so possibly improve compression somewhat.

Alcohol can be used in the same way as kerosene, though more of it should be used, as it evaporates rapidly. To do a thorough job, however, proceed as follows:

Bring one or more pistons, according to the number of cylinders in the engine, to the top of the compression stroke. Both valves will be closed at this point. Fill the combustion chamber *full* of denatured alcohol through any opening, and then close it up, leaving no way of escape. Let it soak for not less than six hours. Treat each cylinder in turn. When all have been treated, run the engine to blow out the carbon.

It is necessary, in treating the engine in this way, that the alcohol should come in actual contact with the carbon. That is the reason for filling the combustion chamber full.

In all probability a good deal of alcohol will leak down and into the lubricating oil.

Run the engine with this adulterated oil for a short time. The alcohol is a cleanser and will give the engine a good washing out.

Then throw away the oil and put in fresh.

To keep the engine clean, put from two to four ounces of alcohol, depending upon the cylinder size, into each cylinder every three or four days, while the engine is hot. Be sure that all openings are closed. Of course it is impossible to have all the valves closed at the same time, but the cylinders that have valves open one day should be treated with valves closed the next time, and so on.

Removing Carbon with Water.

Run the engine at fairly high speed and while running feed water in through the air intake of the carbureter. Give the engine all the water it will take without losing much speed. A great deal of carbon may be loosened and blown out in this way.

When getting rid of carbon by these and similar methods run with the muffler cut-out open to keep carbon from clogging the muffler. Run the engine for a few minutes after the carbon has stopped coming through to make sure that everything has been blown out.

Burning Carbon.

In course of time carbon accumulates no matter what is done to prevent it. It can be removed by scraping or by burning out with oxygen. The heat of the oxygen burning process does no harm, for it is considerably less than the heat of burning gasoline. The burning should be done with the piston at the top of the stroke so that the high temperature will not burn the oil off the cylinder walls and leave them dry.

Scraping off carbon is best done with the cylinder head removed, when the head is removable. Otherwise it is a blind process and it is very difficult to tell how much carbon has been removed and how much is left.

Scrape with the piston at the top of its stroke. Be very careful not to scratch valve seats or other working surfaces. See that no carbon is left in angles and crannies; small patches are likely to become incandescent when the engine is running and cause pre-ignition.

Purpose of Gaskets.

Gaskets are made of more or less resilient material and placed between the metal surfaces to fill all inequalities and prevent leakage. A variety of materials is used, ranging from plain paper up to gaskets

made of a layer of asbestos held between two thin sheets of copper or brass.

When removing a cylinder head or any part that is gasketed work carefully and try to avoid damaging the gasket. This is easy in the case of a copper-asbestos gasket, but is often impossible with gaskets made of sheet packing.

The safest, easiest thing to do if a new gasket is required is to get one from the service station or supply house. Gaskets are die-cut to fit exactly, and they will be properly made and of the right thickness, which is important.

Sometimes it will be found that a sheet-packing gasket has been coated on both sides with shellac or some similar cementing compound. In this case the gasket will be destroyed in the removing process. Sometimes the gasket will be coated only on one side and will stick to one member and let the other come off easily. Let it stay in place if it is in good condition.

Be very sure, before deciding to use an old gasket again, that the surface is absolutely unbroken.

Making Gaskets.

A cylinder-head gasket is usually rather a complicated affair. It is better to buy one ready made if possible; but it is quite possible to make one. If possible use the same material as in the old gasket, and be very sure the thickness is the same.

The gasket must be all in one piece, without breaks or marred surfaces.

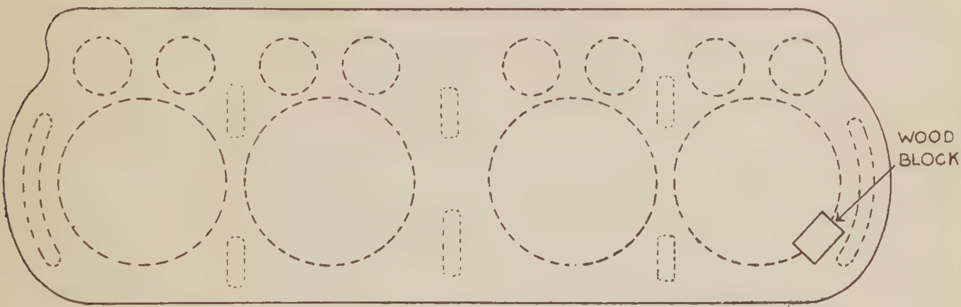
A cylinder-head gasket must withstand a high temperature and high pressure. Plain asbestos sheet will stand the temperature, but not the pressure; it may last for a time, but in all probability will blow out before long. Very good sheet packing, made for the purpose, can be obtained at hardware stores, engineers' supply houses and automobile supply stores, though the latter more commonly stock finished gaskets for popular makes of cars.

Lay the cylinder head on the sheet of packing and mark the outline and cut out the blank. This can be done with a pair of large sharp scissors, except where there are short curves, when a sharp knife is the best. Take care to make clean, clear cuts. For knife work, lay the gasket on a pine board.

Coat the edges of all the openings on the top of the cylinder block with some kind of marking of a color contrasting with that of the packing. Chalk will do for dark-colored packing and blue marking compound for light colors. Anything will do that will leave a mark

on the sheet. Lay the blank gasket accurately in its place. Tap the blank with a hammer and block of wood, moving the block along so as to get an impression of the outlines of all the openings. Tap very gently to avoid bruising the packing.

This part of the work is rendered easier if three or four bolt-holes are cut first and the bolts slipped in to hold the blank from slipping out of place.



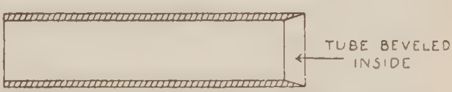
CUTTING A CYLINDER HEAD GASKET

The outline of the cylinders is obtained by blows with a hammer on a wooden block which follows around the edges to be cut. Great care should be taken to make sure that all water connection openings and the holes are cut properly.

You will have a set of sharp lines to guide you in cutting, and they should be followed accurately. *The gasket must not project over the edges of the openings in the least.* It ought to be perfectly flush, but it will do no harm if it is just a shade inside the line—say a thirty-second of an inch.

Mysterious engine troubles have been traced to gaskets that were partly "blind."

Holes for bolts or screws must be cut with great care, and it should be done with a punch. A punch can be bought, or one can be made with little trouble. A piece of steel tubing that will just pass through the hole in the cylinder head is given a cutting edge by beveling it on the inside—not the outside. Even hard-drawn brass tubing will answer well enough to put the holes in one or two gaskets. After marking the places for the holes with a pencil, using the cylinder head as a pattern and being careful not to shift the gasket, punch through with the gasket on a block of wood, hitting a sharp, quick blow.



A HOME-MADE GASKET HOLE CUTTER

This will make clean holes of the proper size for bolts and water connections which may be too small to be cut by means of a hammer or wooden block.

Try the punch on a scrap before cutting the bolt holes. It will sometimes be found that better results can be obtained by turning the punch

while pressing down on it, thus making a sort of tubular knife of it. Use the method that makes the cleanest hole.

Try on the gasket with all the bolts in place, but without the cylinder head on. See that it fits properly. Be particular about it.

Look carefully to see if there are any doubtful-looking places where the gasket is narrow. This is where trouble is most likely to occur. If the gasket is not perfect, make another, using the "failure" for a pattern. It is easier to do this than to pull things down later and do it all over again because the gasket leaks.

Put the gasket on as the old one was put on. If one side was found free, rub one side of the new gasket with graphite to keep it from sticking. The other side and the surface on which it goes are to be coated with shellac. Use a brush for this, put the shellac on quickly but without slopping it over places where it should not go, and get the gasket in place as soon as possible. See that it lies perfectly flat. Put the cylinder head in place carefully. Screw down the nuts or the screws, as the case may be, until they just rest on the head. Then tighten them a turn at a time in rotation, so that all will pull down evenly.

Do not pull down one nut, or part of the nuts, while others are loose.

TIGHTEN CYLINDER HEAD BOLTS EVENLY

If one side is screwed down tightly while the other is left loose, the gasket will be compressed on one side and forced out of shape so that even when the pressure is equalized the gasket will still be of unequal thickness.

Tighten each a little at a time. Failure to observe this is likely to result in a leaky gasket.

After the engine has run for a while and become warmed up it will be possible to tighten down a little more. Be careful not to overdo it and strip threads or break off bolts—which is an exceedingly unpleasant trouble to rectify, as a rule.

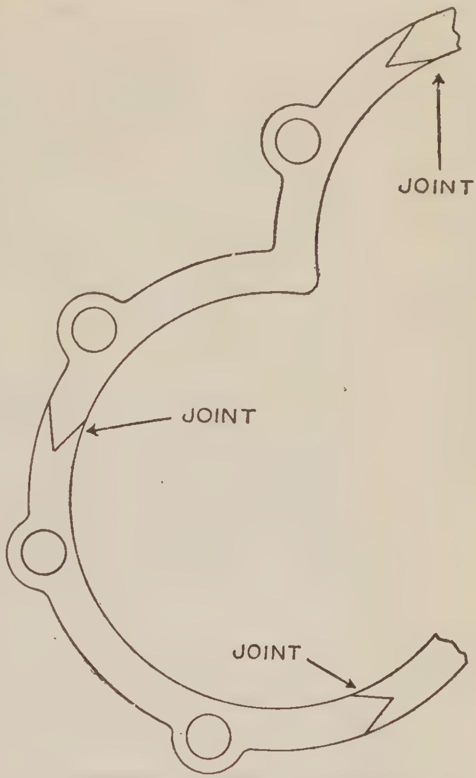
Gaskets for Cool Places.

Gaskets for parts not subjected to much heat or pressure may be of paper, cork composition sheet or the like. The cork composition makes a good gasket for holding oil and for joints that are rough and require a good deal of filling, for it is very elastic. It is rather thick and should not be used where a thinner gasket has been used, as a rule, though no harm can be done if the extra thickness does not affect any of

the parts. For instance a slightly heavier gasket between the carburetor and the intake manifold can do no harm.

One good thing about cork composition is that it can be used to advantage for making in sections gaskets that are narrow and of very irregular and complex form, as gaskets for timing-gear housings sometime are. Such a gasket is difficult to make in one piece. Make the gasket in as few sections as possible, and make V-shaped joints. Have the angles correspond accurately and butt them together closely. Make the joints where the gasket is widest. Have no joints at bolt-holes. When one section is cut, stick it in place with shellac; then put the next in place in the same way, and so on. When pressure is put on the joined places will be forced against each other and will hold oil perfectly.

This method must not be used where there is pressure. It will not do at all. Joined gaskets can only be made of very elastic material, which will compress and expand at the joined places.



CUTTING A GASKET IN SECTIONS
This method can only be employed in the case of a cork gasket used to make an oil or liquid-tight joint. It cannot be used where liquid or air are held under pressure.

Paper Gaskets.

Special paper is made for gaskets, but good tough, heavy wrapping paper works very well, especially if it is given a coating of linseed oil. A paper gasket can be marked for cutting out in much the same way as described for the cylinder-head gasket; but the tapping is not necessary. Rub your finger along instead of using a block and hammer. Make the gasket first and oil it afterwards. Be careful in putting it on, for it is easily wrinkled or torn.

Gasket Essentials.

Here are the main things to remember in applying gaskets:

Use a ready-made gasket, exactly the same as the old one, if possible.

If you have to make a gasket, make it of the same material as the old one, or of material of the same character.

The new gasket must be the same thickness as the old one. The old gasket, however, will be compressed and somewhat thinner, after having been under pressure, than the new material.

A gasket must be a perfect fit. If it has to be pulled and distorted to get it into place it is likely to buckle and leak. This is particularly true of gaskets under pressure. Do not depend upon shellac or any other compound to fill up bad places in a gasket.

The entire surface of the gasket must be clean and unbroken. If there is a bad spot it will sooner or later make trouble. Do not use plain asbestos sheet for gaskets to hold water. Water softens the asbestos as it does blotting-paper and makes it very weak.

Fitting New Piston Rings.

If compression is weak, despite proper lubrication, tight valves and tight cylinder head—make certain of these points—examine the piston rings. If gas leaks past them the fact will be indicated by dark places where the rings do not bear against the cylinder walls sufficiently, if at all. Where the rings bear they will be bright and polished. The rings should bear evenly at all points.

Often it will be found that there is indication of leakage on each side of the joint or points. This may be due to inaccurate finishing of the ring or to wear.

If the rings show leakage and there is reason to assume that the cylinders are not badly worn, a new set of rings will often bring about an improvement.

Before deciding on a new set of rings, be sure that leakage is actually due to wear and not to misplacement of the rings. If, after an engine has been running for some time, the pistons are removed and replaced with the positions of the rings changed, leakage is almost sure to occur. The reason is that the rings wear so that they accurately fit the slight oval of the cylinder; if they are turned, however, they will no longer fit.

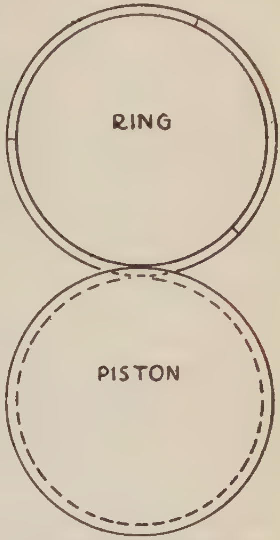
This leads up to the warning to be most careful to see that rings are put back exactly as they came out. It requires a good deal of care, but it is well worth while, for once the rings are moved it is a matter of the greatest difficulty—almost an impossibility—to get them where they belong again.

For worn cylinders some of the sectional rings on the market are very satisfactory, if the wear is not too great, as they can expand unequally to some extent and fill the space.

Try the new rings in the grooves first to see that they are of the

right width. They should just slip in, without binding or tightness, but also without shake. Rings that are loose in the grooves will leak and will cause a slight knock in many cases.

Try the ring by rolling it in the groove without putting it over the piston. See that the groove is deep enough to take the ring. The groove should be just the smallest fraction of an inch deeper than the ring. If the groove is not deep enough the ring will project and it will be impossible to get the piston into the cylinder. Take the pistons and a sample ring to a good automobile machinist and let him deepen the grooves.

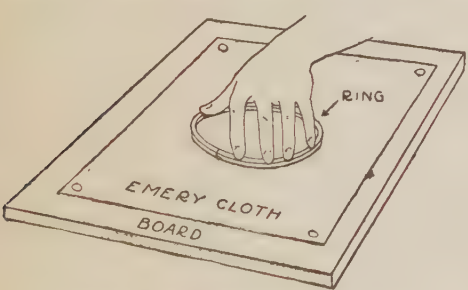


FITTING PISTON RINGS

If the back of the ring is rolled around in its groove, high spots which would make it stick can be readily discovered.

If the rings are a little too tight in the grooves—that is, if they will go in only by forcing—they can be fitted with the exercise of a little care and patience.

Take a sheet of No. 1 emery cloth and tack it on a perfectly flat, smooth board. Lay the ring down on the emery cloth and rub it around with a circular motion, taking in as much as possible of the whole sheet of emery cloth. Spread the fingers to as many points of the ring as possible, so as to equalize the pressure, and shift the position of the hand on the ring frequently, the idea being to avoid taking more off one place than another. Work on only one side of the ring. Try the ring from time to time, first wiping it clean of emery dust. Try it all round—not at one point only—to check any tendency to excessive reduction in spots.



TAKING OFF THE "HIGH SPOTS"

A circular sliding motion of the ring on flat emery cloth will serve to smooth the surface evenly. Care should be taken not to make the ring loose in its groove.

When the ring fits perfectly all round, wash it carefully in gasoline to get rid of every trace of emery.

Do not attempt to cut down either the outer or inner circumference of the ring in this or any other way. It will spoil the ring.

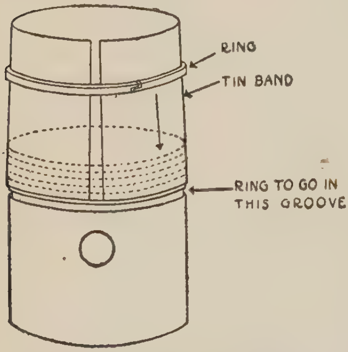
If the ring is so wide that it will not enter the groove at all a narrower ring must be used or the grooves must be widened by the machinist. If this is necessary, give him the pistons and all the rings and let him do the whole job. A heavy lathe is necessary for this work.

Putting On Rings.

Piston rings are of cast iron. They are very elastic within narrow limits, but very brittle and easily broken by rough handling. They can be "stretched" enough to go over the piston, but that is about all, and the stretching must be cautiously done.

Never take apart a ring that is made in several sections. The ring is finished finally with all the parts in place, and if their relative places are changed it is almost certain that they will not fit properly, even though they may appear to be all right.

About the easiest and safest way to get rings into their grooves is to take a piece of tin or other thin sheet metal large enough to wrap almost all the way around the piston and to reach from the lowest groove to a couple of inches above the top of the piston.



A DEVICE FOR REPLACING PISTON RINGS
Rings are slightly elastic but are also brittle and easily broken if subjected to undue strain in an attempt to force them over the cylinder without the aid of the means herewith described.

Put the tin guide around the piston with its lower edge just above the upper edge of the bottom groove. Slip the ring over the projecting end of the guide, which can be contracted enough to allow this. Slide the ring down the guide—which, by the way, should be oiled—and it will expand gradually and evenly, until it snaps into the groove. Move the guide up to the next ring groove and put in the ring in the same way, and so on. This is easier and safer than using a number of separate strips of tin, especially for the inexperienced.

When all the rings are on, see that the joints "break"—that is, that they are spaced as far apart as possible. In the case of a ring with a single joint, three rings to a piston, move the joints so that each will be a third of the circumference of the piston from the next. Do not have the joint of the bottom ring in line with that of the top ring. When installing sectional rings, "break" the joints in the same way, though of course there will be less distance between them.

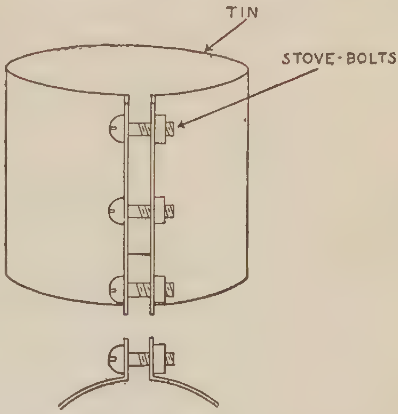
Putting In Pistons.

When the rings are in their grooves they will be larger than the piston. When in the cylinder they are compressed to the same diameter as the cylinder. They must be compressed to get the piston in.

Single-piece rings can sometimes be compressed with the fingers, one ring at a time, as the piston is being inserted. This requires some skill to avoid damaging the rings, and it involves the risk of severely pinch-

ing the fingers. Sectional rings cannot be managed in this way.

The safest way for rings of all kinds, and a way that saves the most time in the long run, is to make a clamp of sheet metal, such as heavy tin. The clamp is simply a piece of tin a little more than wide enough to cover all the rings and long enough to wrap around the piston after the two ends have been turned up to form flanges for small bolts, such as stove-bolts, to pull the clamp tight.



AN AID TO PISTON INSTALLATION

The rings interfere with an easy replacement of the piston. Pinched fingers will result if the repair man uses his fingers to press the rings. The method here shown will enable pistons to be replaced without damage to rings or fingers.

When ready to put in the piston oil it and the rings liberally, oil the inside of the clamp, put it over the rings and screw up the bolts to draw it in and compress the rings. Tap gently the outside of the clamp, over the rings, with a screwdriver handle or some other wooden object, to ease the rings into place, and keep on screwing up until the rings are flush with the piston surface. The clamp should not be very tight when this is done. Leave as much of the top of the piston projecting as possible, if the piston is to be inserted from the bottom of the cylinder, or leave the bottom of the piston projecting if it is to be inserted through the top.

Insert the projecting end of the piston into the cylinder, and *be careful to get it in straight and square.* Then push. The piston should slip through the clamp, which will butt against the top of the cylinder and hold each ring, as it passes, compressed until it enters the cylinder.

If you cannot push the piston through the clamp, the latter is too tight; loosen the clamp screws just a trifle and try again. Make sure that the rings are not allowed to expand, however, just before they reach the cylinder. Do not use too much force, for a ring may be caught, and forcing would probably break it, or at least mar its edges, which might cause scratching of the cylinder walls later on.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER III

The practical reasons why cylinders and pistons should be kept in good condition.

How cylinder and piston wear occurs, and why.

What to do when cylinders are worn.

How cylinders become scored.

What to do with scored cylinders.

What makes pistons seize or "freeze."

What indicates the approach of seizing.

What to do when pistons seize.

How to provide extra cylinder lubrication to prevent seizing.

How and why carbon accumulates.

How to prevent the accumulation of carbon with kerosene, water, alcohol, or burning.

How to scrape carbon.

How to make cylinder head and other gaskets.

How to make a tool for cutting bolt-holes in gaskets.

How to make gaskets for cool places.

What materials should be used for gaskets.

The essential points in gasket work.

How to tell if new piston rings are needed.

How to tell if rings fit properly.

How to fit rings that are too tight.

Why piston rings leak.

How to put rings in their grooves.

How to make a guide for putting rings in grooves.

How to put pistons in cylinders without injuring rings.

How to make a clamp for putting pistons in cylinders.

CHAPTER IV

VALVES

Why Valves are Vital.

Valves, valve setting and valve-operating mechanism are of such prime importance in the operation of the engine that to a great extent the design of the whole motor hinges on these parts, and, in particular, upon the sizes of the valves—or, to be more accurate, upon the amount of clear space allowed by the valves for the passage of gas, both in-going and out-going.

The valves exert a controlling influence upon the speed of the engine and therefore upon its maximum power for a given bore and stroke.

Even small valves will permit an engine to operate efficiently at low speeds, assuming, of course, that they are set to open and close at the correct time. This is because the speed of the gases through the valve openings is moderate, so that the flow is free and easy, just as the flow of water through a pipe is easy if the volume of water is moderate in proportion to the size of the pipe.

How Valves Affect Speed.

When the speed of the engine is increased, it becomes necessary to draw gas faster through the intake valves and expel it faster through the exhaust valves. The higher the speed the more power it requires to do this.

To illustrate this, take an empty pipe in your mouth and draw air through it at the rate at which you would draw ordinarily in smoking. Practically no effort is required. This corresponds to the "suction" of an engine running at moderate speed.

Try to fill your lungs rapidly with air drawn through the pipe-stem, however, and at once the resistance to the flow of air will be felt. The faster you draw in the air the harder it will be, and very soon the point is reached where you cannot draw any faster, no matter how hard you try. Try to breathe rapidly—in and out—through the pipe and the effect will be intensified. You cannot get your lungs full, and you cannot get them emptied.

This is precisely what happens with the engine. When the speed

rises to a certain point it cannot get its cylinders fully charged and it cannot get them entirely emptied on the exhaust stroke.

Small Valves.

Just as you must use a lot of power to get your breath in and out through the pipe-stem, so the engine must use a lot of power to get its gas in and out. This power, used up internally, must be subtracted from the power delivered by the engine at the clutch. The engine uses up part of its own energy in keeping itself going, and the proportion of energy so used increases with the speed.

At the same time the quantity of gas taken in on the intake stroke decreases. The piston shoots downward on the intake stroke so fast that when it reaches the bottom there is still a partial vacuum in the cylinder —that is, there is only part of a charge of combustible gas. With less than a full charge, the pressure of the explosion will be just so much short of the full normal pressure, which means a further loss of power. Finally, all the exhaust gas cannot be crowded out through the restricted valve passages in the short time available during the exhaust stroke, so that in addition to losing power in creating the pressure to force the exhaust out—remember how hard it was to breathe out rapidly through your pipe-stem—some of the dead gas is trapped when the exhaust valve closes and it mixes with the next incoming charge. Of course a certain amount of dead gas is always left over to mingle with the fresh gas, even at moderate speed; but the quantity increases rapidly with the speed.

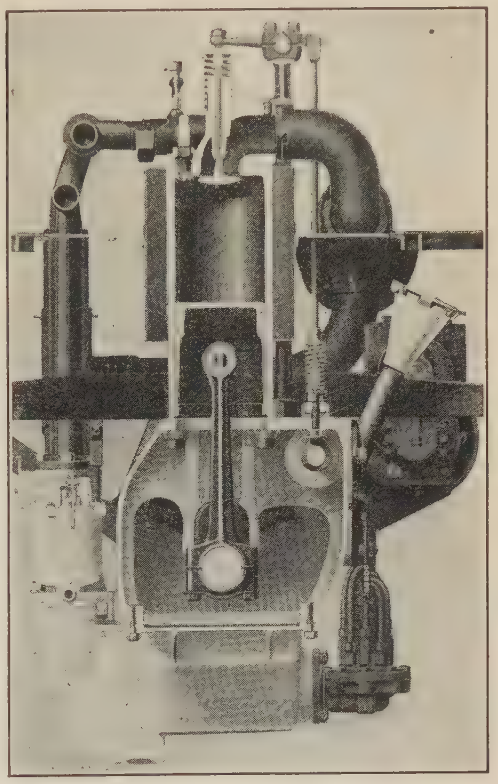
SO WHEN AN ENGINE IS SPEEDED UP THIS IS WHAT HAPPENS:

At first the power increases approximately in direct proportion to the speed. This is because there is an increase in the number of explosions in a given time; other things being equal, the power of the engine is proportionate to the number of explosions per second, or per minute. But when the explosions grow weaker and at the same time more power is absorbed simply in getting the gases in and out, the increase of power becomes slower and slower, until finally the point is reached where the engine ceases to increase its power even though its speed may be still further increased. In many engines the power will actually become less as the speed becomes greater, beyond a certain point.

Thus it happens that when an engine is run at the very highest speed of which it is capable, the power will be less than at a more moderate speed.

Increasing the area of the valve passages in any way permits the

engine to continue to increase its power to higher speeds. For instance, an engine that, with a given-sized valve will continue to increase its power until it develops, say, 30 horsepower at 2,000 revolutions per minute and then can go no further, may, if larger valve passages are provided, get its gas in and out so much more easily that the power will go on increasing up to 3,000 revolutions per minute, reaching perhaps 40 horsepower. There may be little or no increase of power at low speeds, the only difference being that the engine will run faster and deliver more power at high speed. So an engine with large valves, running at high speed, may be a smaller engine, for its power, than an engine with smaller valves which necessarily runs more slowly. This is the idea back of the high-speed engine.



LARGE VALVE PASSAGES GIVE POWER

Unobstructed openings, wide, sweeping turns and large valves allow the gas to be sucked in and forced out with a minimum of loss.

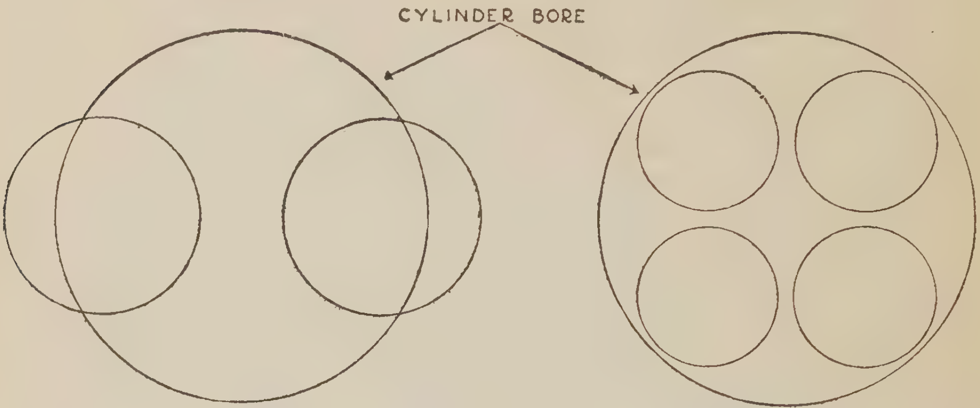
16 and 24 Valves.

All this goes to explain the activity that has been manifested in the last few years in the production of engines with four valves per cylinder—two exhaust valves and two intake valves—and the excellent results that have been obtained from such engines. Mainly it is due to the rapidity with which the gas is moved and the small amount of power that is required to draw it in and expel it. A four-cylinder engine with two intake and two exhaust valves per cylinder is commonly called a sixteen-valve engine, and a six is a twenty-four-valve engine.

Why Not Large Valves?

It might be thought that the simplest thing would be merely to make the valves very large. Practically, however, this will not work out. Large valves are more difficult to keep in condition than small valves; they warp more easily and are harder to grind. They are heavier, and when operated at high speed they pound hard on their seats, making a

good deal of noise, for very heavy springs are required to close them promptly, all of which adds to the power needed to move them—by no means a small item—and also increases very greatly the pressures on the cams, camshaft bearings and other parts. A further important point is that a large valve takes up a great deal of space and tends to



WHY FOUR SMALL VALVES ARE BETTER THAN TWO LARGE VALVES

The four small valves shown above will admit and expel approximately the same amount of gas as the two large valves at the left. The design at the left is impractical, however, because of the large area occupied by the valves which would give a compression space so large that the proper compression of the mixture could not be obtained.

increase the bulk and weight of the engine and to complicate the design of the combustion chamber. For a given space, weight and power absorption, much better results can be obtained by using two comparatively small valves than one large one having the same total passage area.

Operating Conditions Important.

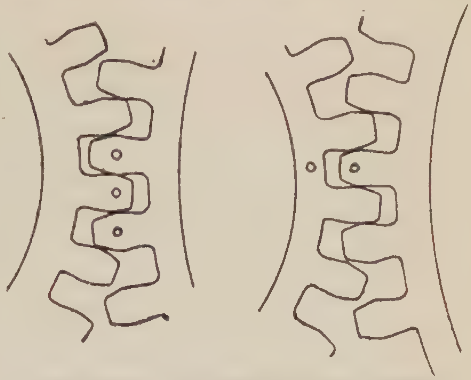
All the foregoing indicates that it is in the highest degree important that the valves should be maintained at the highest possible point of efficiency. Fortunately, the valves and their operation and arrangement give more trouble to the designer than anyone else. The user's part is comparatively simple.

The valve timing is too important to be meddled with. It is fixed by the proper meshing of the gears driving the camshaft, and the user's only care is to be absolutely certain that if the gears are unmeshed, they are put together precisely in the original way.

Timing.

Before unmeshing timing gears, look for marks indicating how they should go together. If there are no marks, make marks of your own.

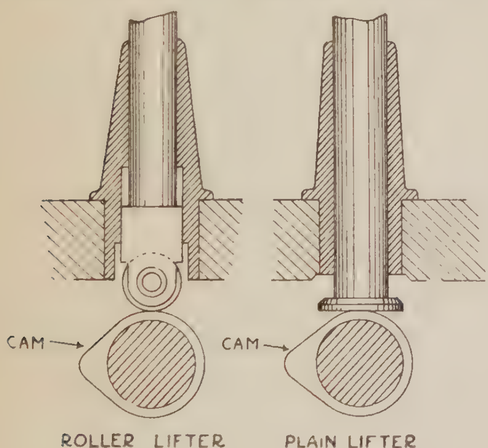
If there are only two gears, one on the crankshaft and the other on the camshaft, make a "pop-mark" with a small prick-punch on one tooth, say of the gear on the crankshaft, and similarly mark two teeth on the camshaft gear, one on each side of the tooth already marked. Then when putting the gears together it is necessary only to put the single pop-mark between the marks on the other gear. If there are three gears—one simply an intermediate to avoid the necessity for very large gears—mark three teeth, as described, where the crankshaft and the intermediate gears mesh, and three where the intermediate and the camshaft gears mesh.



TWO WAYS OF MARKING GEAR TEETH

The gears drive the cam-shaft which actuates the valves, and it is necessary that exactly the same teeth mesh when the gears are replaced.

By observing these precautions the re-timing of an engine will be unnecessary. If for any reason re-timing should be necessary, it must be done in the particular way fixed by the design of the particular engine. Valve timing differs so widely that there is no rule that is useful as a general guide. Look up your instruction book, or give the job to a repairman who knows, or find out from the maker of the engine. Don't try to do any valve timing—unless you are an expert or you are forced to do the work yourself.



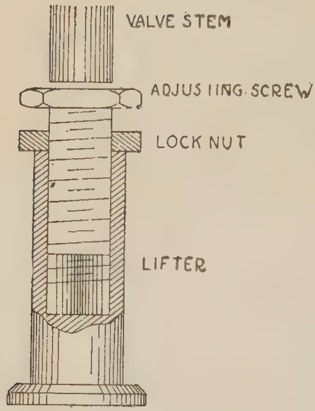
TWO TYPES OF VALVE LIFTERS

The roller type wears but little; the plain, flat type is sometimes designed with the valve stem set "off center" so that the valve stem is partially revolved each time that it is lifted by the cam, thus distributing and equalizing the wear.

Lifter Adjustment.

There are many ways of adjusting valve lifters or tappets, but in all cases the object is to maintain exactly the right space between the lifter and the end of the valve-stem, upon which it pushes.

This is important because if there is too much space the valve will not begin to open until the lifter has traveled through the open space. That means that the valve will open late and delay the flow of gas, whether intake or exhaust. Further, it means that the valve will not open fully, so that the flow of gas will be restricted. Finally, it means that the valve will close



VALVE LIFTER ADJUSTMENTS

Too much clearance between the valve stem and lifter will make a noisy motor, will cause bad timing, and will keep the valve from opening to its full height.

too soon, still further cutting down the time during which the gas can flow.

Bearing in mind what has been said about the importance of a free flow of gas, the need for correct tappet adjustment will be appreciated.

The clicking noise made by the lifters striking the valve-stems when there is too much space is the smallest of the evils, but it serves as an indication of the need for adjustment that should be heeded. In fact, it should be anticipated; the wear should not be allowed to reach such a point that operation will be unduly noisy.

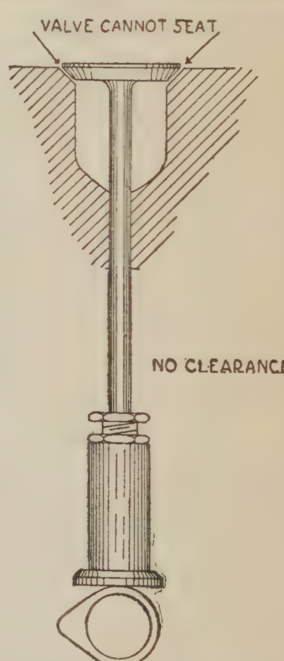
Valve Adjustment.

Adjustment must be so made that when the valve is closed there will be a very small space between lifter and valve-stem. The thickness of a piece of thin paper is sufficient.

If the adjustment is made when the engine is cold it will be wrong when the engine is at its normal working temperature. This is because the expansion of the metals will tend to close up the gap, so that the tappet will never drop quite clear of the valve stem, and the valve will be held slightly open when it should be closed.

Adjust the lifters while the engine is hot, if possible. If this cannot conveniently be done for any reason, leave two or three times the normal space in adjusting the cold engine, and then test the adjustment when the engine is good and hot. There should be just room to slip in a piece of thin paper. If there is not room for this, or if there is too much space, adjust accordingly.

In some cases the proper clearance when the engine is cold is given by the instruction book, allowance being made for expansion. When adjusting for cold clearance, always make a test when the engine is hot, for expansion may differ somewhat in different engines of the same make and model.



INSUFFICIENT CLEARANCE

In this case the valve is not allowed to seat and a portion of the charge will escape.

A good plan is to find a strip of sheet metal that exactly fits the space when the engine is cold and the valves properly adjusted. Then it can always be used as a gauge for adjusting cold.

When the adjusting device is held by a lock-nut or jam-nut, do not test with the lock-nut loose. The final tightening usually makes a difference in the adjustment. Test with everything tight.

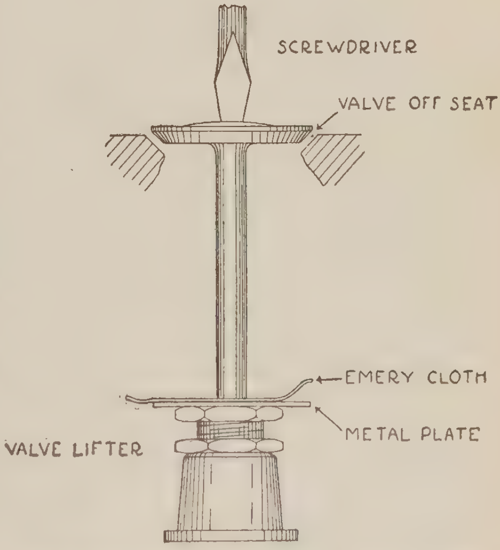
Make the adjustments exactly alike on all the lifters. This not only insures the best possible results from all cylinders, so far as the valve adjustment is concerned, but it prevents the "limping" that may, and not infrequently does, result from unequal adjustment.

In a few engines it will be found that no means are provided for adjustment. When wear occurs, however, it can be taken up by means of adjusters made for the purpose, which are simply little tubular clips of spring steel which slip over the ends of the valve stems. Little discs of metal can be inserted to make up any adjustment needed.

If after grinding the valves on such an engine it is found that there is not enough clearance, so that the valves will always rest on the tappets, the ends of the valve-stems must be filed off or, if they are hardened, they must be ground.

Do this work very carefully. In the first place there is danger of taking off too much, in which case adjusters would have to be used. In the second place, there is danger of leaving the end of the stem out of square, in which case only one point would touch the lifter and there would be rapid wear and a little hole would be made; or, in a lifter of the type that turns when in operation, a circular groove would be worn in it.

Here is a way of making the end of the stem true.

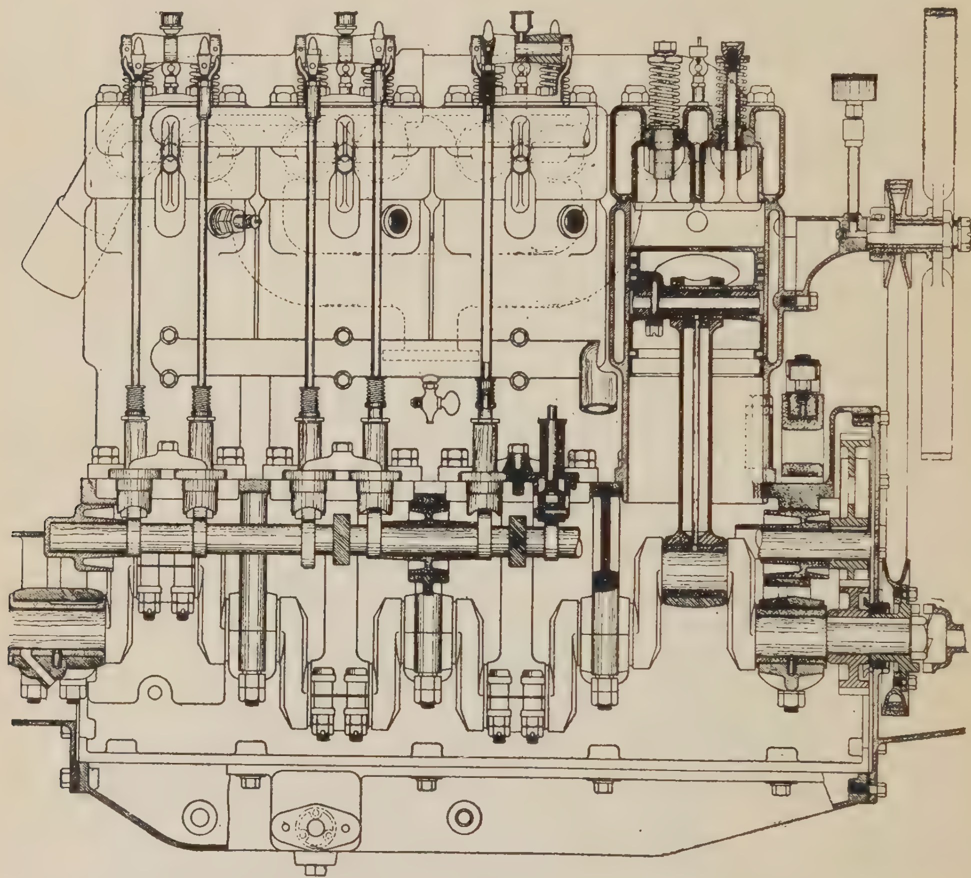


GRINDING THE END OF THE VALVE STEM
The valve stem should be flat or slightly rounded, with its high spot at the center. It is simpler to grind the end flat, as here shown.

When you have filed or ground off almost, but not quite enough, lay a bit of No. 1 or No. 1½ emery cloth on the valve lifter, if it is not much worn. If it is considerably worn, put the emery cloth on a scrap of sheet metal resting on the lifter. Put the valve in its place and the end of the stem will rest on the emery cloth. Turn the valve briskly round and round with a brace,

using about the same pressure as in grinding. This will grind down the end of the stem and leave it just a trifle convex. If the stem is much out of square the emery marks will show it, and a little more should be filed or ground off until the emery cloth can smooth it all over.

The principles embodied in the foregoing apply to all engines with



THE OPERATING MECHANISM OF THE OVERHEAD VALVE ENGINE

In this type of engine the lifters are the same as those already described. The lifters push against the rocker arms, however, the other ends of which force the valve downward into the head. The lifter adjustment, however, is sufficient to take up the wear which may occur on the push-rods, rocker arms and the valve stems.

poppet-valves. Of course the details of the valve-operating mechanism of engines differ greatly, especially in the case of the overhead valve types. The principles understood, however, the rest is simply a matter of mixing them with common-sense and applying them to your engine, with the aid of the always-useful instruction book.

In adjusting valves, as in all other work on the car, find out exactly why you do a given thing, what result you expect to get, and you will

have no serious difficulty in coming out right. But if you try to follow blindly a set of directions, without knowing why, you are much more likely to end up in the wrong place. And you won't even know why you are wrong.

Why Valves Need Grinding.

The constant hammering of the valves on their seats causes wear, and such wear is not quite equal at all points. In time the points of greatest wear separate sufficiently to allow leakage, and this in itself increases the wear, especially in the exhaust valves. Grinding cuts down the high places to the same level as the worn places, smooths up the surfaces and makes them gas-tight again.

The exhaust valves suffer more than the intake valves, for they are always at a very high temperature, which not only reduces their ability to resist the effects of pounding, but causes pitting, or the formation of little depressions, in the surfaces. There is also some tendency to warp from the heat, though a good valve rarely gives much trouble from this cause.

How to Grind Valves.

The first operation is to remove the valves, and the worst part of this is usually taking off the springs, though this is not quite so troublesome as getting them back. The main thing is to get the spring compressed so that the pin or key holding it at the bottom can be removed. It pays to invest in a tool mode for the purpose, which does not cost much and saves a lot of time and pinched fingers. In the case of a big engine it is difficult to do much without the tool.

Slack back the tappet adjustment so that there will be at least a sixteenth of an inch clearance under the end of the valve stem. This is done because as the valve is ground, it is allowed to set closer to the lifter, and if there is not sufficient clearance the stem may rest on the lifter and keep the valve off its seat so that it will not grind.

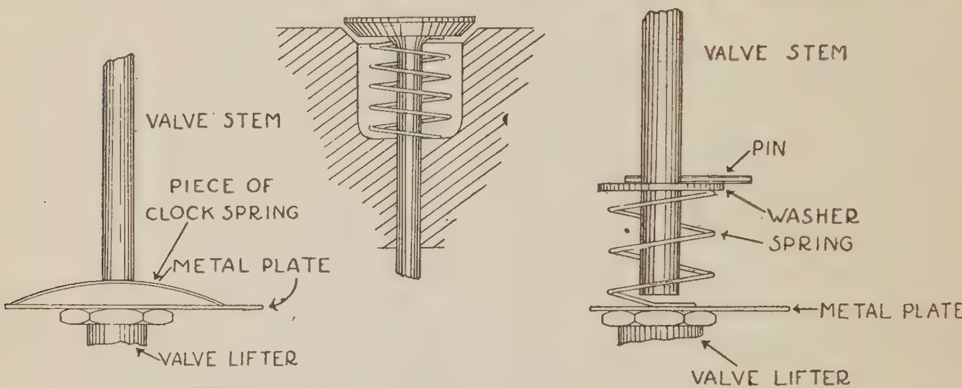
Clean the valve carefully, scraping off carbon if there is any, and washing it with gasoline all over. Clean the valve seat and all parts within reach in the same way. Stuff rags or waste into all openings leading into the cylinder to prevent grinding compound from getting in. Do all that can be done to keep the compound from getting anywhere except on the surfaces to be ground, for it is most destructive in the wrong place.

If it can conveniently be arranged, put a light coiled spring under the valve head, or arrange it in any way so that the valve will not go down on its seat unless lightly pressed. This allows the valve to rise

from its seat during the grinding process whenever pressure is relaxed.

Use a fine grinding compound, which is obtainable at any supply store ready for use. Two grades, fine and coarse, often are put up in the same box, in different compartments. Use the fine grade. The coarse grade is usually too coarse for ordinary work and it is easy for the inexpert grinder to score and cut the valve and seat. Flour emery mixed with oil can be used with just as good results as the prepared compound, but it is more bothersome.

Dab the valve lightly with the compound. Only a little is needed—a light film. Dab a little oil on the valve seat. Put the valve in place



THREE WAYS OF HOLDING THE VALVE OFF ITS SEAT

As soon as the grinding pressure is removed, the valve should lift off its seat so that it may be turned to a new grinding position. It is more convenient to use springs than to lift it by hand each time.

and turn it, under light pressure, back and forth about a quarter of a turn. Use a screw-driver or a brace with a screw-driver bit. Every half dozen or so of turns let the valve come up off its seat, if a spring is used, or put your finger under the end of the stem and raise it, if there is no spring, and give it a turn to bring it into a new position before starting to grind again.

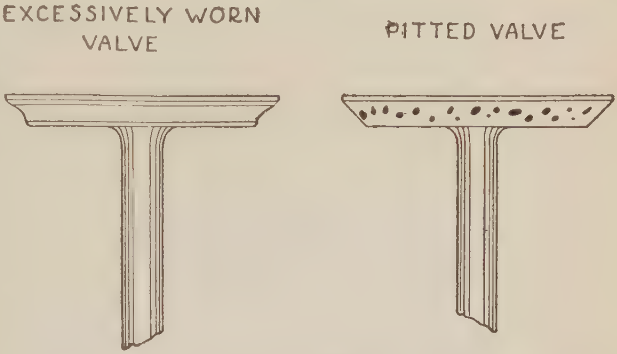
What follows depends a good deal on the condition of the valve. If it was in fair condition before grinding, with only slight indications of leakage, grind until there is a feeling that the compound has ceased to "bite." Then lift the valve, smear a little oil on it, but no more compound, grind again for a few minutes as before, and then wipe both valve and seat clean, put them together and give a couple of quarter turns and look to see if enough grinding has been done.

The marks should show that there is contact over at least half the width of the surfaces. It is not necessary, and moreover it is very difficult, to get really good contact over the whole surface.

In trying the valve do not press hard, do not move the valve more

than a few times and do not turn more than quarter of a circle or about that. You can make a leaky valve look like a perfectly ground job by pressing hard, or giving a few complete turns. But this will not make it a good job.

If the valve was in bad shape, a good deal of grinding will be required and fresh compound must be put on from time to time. Wipe off the old stuff each time to give the new charge full play. This speeds up the grinding. Put on a little oil occasionally to keep the valve from grinding dry. In fact, it is a good idea to mix a little of the compound with oil to have it ready for use.



VALVES WHICH NEED GRINDING

The one on the left is so badly worn that it would probably need re-seating with a special tool. The one on the right is pitted from the action of carbon and the heat. This condition, however, can be remedied by proper grinding.

As the grinding nears completion, stop putting on fresh compound, but instead put on a little oil. This will make the cut finer and finer, and a smoother surface will result. The smoother and better finished the final surface, the longer the valve will run without regrinding.

The sense of feeling is important in grinding valves. There is rather a strong tendency for the compound to "ball up" and cut grooves. It is to avoid this that the valve is raised and shifted around. But a tendency to cut grooves can be felt; there will be a grating feeling, more harsh than the grating of the new compound and quite distinguishable from it. This is a danger signal. Lift the valve, spread the compound with a finger and put on less pressure next time.

TESTING THE VALVE

When all pencil marks or chalk marks are rubbed off throughout the greater part of their length, a good, gas-tight seat has been secured.

When you think the job is finished, wipe valve and seat very clean and make half a dozen marks across the valve seat with a soft pencil, chalk, or anything that will leave a light mark. Set the valve down and give it a couple of quarter turns, just as you would in grinding. If

the job is finished all the marks will be wiped away along the zone of contact. If some of the marks are untouched, go on grinding, for there will be a leak if you do not.

Remember that in making this test too much pressure or too much turning will give a false story. Very slight movement under very slight pressure will take out the marks on a properly ground valve.

If you want to do an extra good job, put a little graphite on the valve seat along with the old, nearly worn-out grinding compound for the last stage of the grinding. Apply just a trifle more pressure than before. Use plenty of oil. The result will be an exceedingly smooth finish. Some mechanics like to give the valve a final rubbing in with only graphite and oil, turning it through a complete circle. This is simply a polishing operation.

Wipe away all the mess of grinding compound and oil. A rag dampened with kerosene or gasoline is good for this. Avoid washing compound down into the valve-stem guide, where it can do a lot of damage, even if there is not much of it.

What To Do With Very Bad Valves.

If a reasonable amount of grinding will not bring the valve to a good seating, as may happen when grinding is long overdue and is more likely to happen with the exhaust valves, do not keep on in the hope of "reaching bottom" sometime. The valve seat will unnecessarily cut down and you will waste time and energy. Put in a new valve or, if this is not practicable or convenient, get the old valve trued up by a repairman. In either case it is necessary to grind in.

If ridges project above or below the seating zone, either on the valve or the seat, do not grind until the ridges have been removed. If you are somewhat skilled with tools, you can do the job with a fine half-round file or perhaps a scraper. If you are not, the repairman can do it in short order with a special reamer made for the purpose, and while he is about it he should true up the valves, for the cutting process is almost sure to slightly change the angle of the bevel. Finally, they must be ground in. Do not try to grind in very badly pitted valves. Have them trued up or get new ones.

If the valve is in a cage a test for tightness can be made by turning the cage upside down and pouring a little gasoline in. Gasoline will go through an exceedingly minute crack, and if the valve holds it, it can be considered tight enough. A valve in a removable cylinder head can be tested in the same way.

Adjustment Necessary After Grinding.

As the grinding allows the valve to drop lower, readjustment of the lifters will be necessary every time grinding is done, even if the adjustment was perfect before grinding. If you omit this you will probably find that some of the valves will not seat. The grinding makes more difference in this respect than the inexperienced user would expect.

What Happens When Valve Stems Wear.

Valve stems are subject to a good deal of wear, more in some engines than in others. When the stems are much worn there is no use keeping the valves; get new ones and grind them in.

Worn valve stems allow the valve to move laterally, and the result is that the valve does not come down truly on its seat and so very quickly wears to the point of leaking, no matter how often it is ground. Further, a surprising amount of air can be drawn into the engine between worn valve-stems and their guides, and missing and loss of power often result.

Occasionally it will be found that the stems do not get enough oil, and they will wear fast and not infrequently set up a little intermittent squeaking that may be quite baffling. A squirt from an oil-can will settle the trouble for the time being, but the stems should be oiled every day at least if they tend to run dry, and if possible should be fitted with little oilers which are made for the purpose and are sold at most supply stores. These are simply little metal-cased felt pads that fit around the stems at the top and hold enough oil to last for some time.

If the stems are much worn, it may be that the guides are worn too, in which case new valves will only partly remedy the trouble. Where the guides are simply holes reamed in the engine casting there is no remedy except to fit valves with over-size stems, which is usually a job for the repairman. If the guides are removable, new guides and new valves will restore things to the original condition of tightness.

Cast iron makes a remarkably durable bearing surface under proper conditions, and usually the valve stems running in plain holes in the cast iron will wear much faster than the holes.

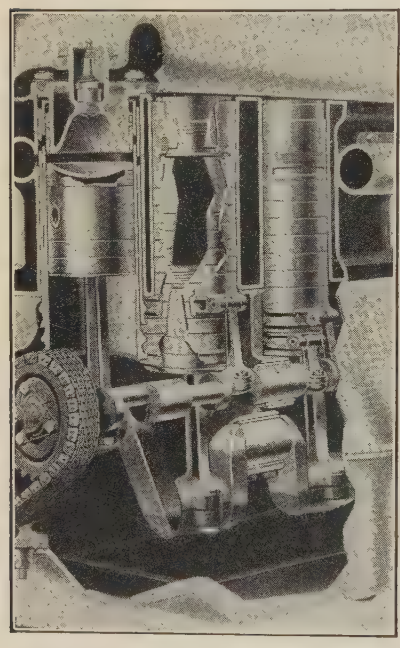
Result of Wear in Rollers.

Where there are rollers at the bottom of the valve-lifters to take the thrust of the cams it occasionally happens that a roller sticks, especially in a new engine, and so takes all the wear in one place. Ex-

amine the rollers when opportunity offers. This, however, is not a common trouble.

After a long running the rollers may become worn in their bearing, so that there is a good deal of shake or lost motion. This means that valve operation will be affected exactly as if there was too much space between the lifter and the valve-stem. Make good the trouble in the way provided in your particular engine. Keep a lookout for rollers worn in one spot. In the hardening operation it may happen that a roller gets through somewhat too soft, or soft in one spot, in which case it will wear too fast or wear too much in one place. Once a spot starts to wear it will continue to wear more rapidly.

Ordinarily such troubles do not occur. All these parts are thoroughly lubricated and are made very hard, so that wear is slight. But it is well to know what *may* happen and to keep an eye open for the unexpected.



SLEEVE VALVES

These are cylindrical in shape and surround the piston. The two sleeves in each cylinder move in opposite directions and pass the port cut in the cylinder at the same time, thus giving a quick opening.

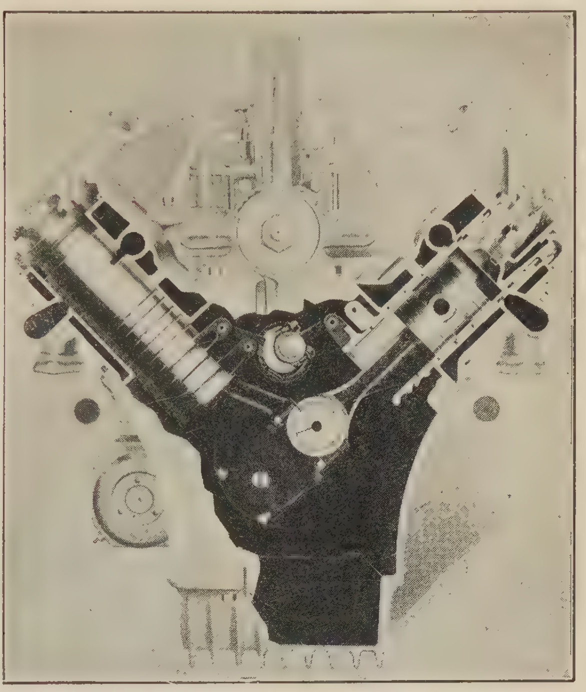
Cam Wear.

Cams are always extremely hard, have broad wearing surfaces and are well lubricated. So they wear comparatively little. If there are indications of excessive wear there is nothing to do but get a new camshaft, for shaft and cams are all in a single piece. Camshaft bearing wear is more common, and has the effect of decreasing the lift of the cams, so that the valve does not get its full opening. Replacement of the bearings as described in Chapter 2, is the remedy.

Sleeve Valves.

Sleeve valves are totally different from poppet valves in every way. They are simply sliding cylinders placed between the piston and the cylinder walls, so that the piston, instead of working against the cylinder walls, as in the ordinary engine, slides inside the inner sleeve valve. Usually there are two sleeves, one next to the piston and one next to the cylinder. Slots cut in the sleeves register with the passages in the top of the cylinder to allow gas to pass, and when the slots do not register the valves are closed. The sleeves are moved up and down by eccentrics and short connecting-rods, the usual camshaft,

lifters and so on being absent. All the eccentrics are mounted on one shaft, just as the cams are all on one shaft, and the shaft is usually driven by a silent chain instead of by gears, the chain and sprocket occupying the usual casing at the front of the engine.



THE EIGHT-CYLINDER SLEEVE VALVE ENGINE

The cylinder at the left is shown as the two sleeves are passing the intake port which corresponds to the full opening of the intake valve on the poppet type of engine.

Sleeve-valve Engine Troubles.

A sleeve-valve engine kept in good condition is unlikely to give trouble due to valves. The surfaces are so large that wear is practically negligible, given proper lubrication. But inadequate lubrication can cause a great deal of trouble, also because of the very large surfaces, for without oil the valves will stick or freeze and hold so hard that the valve-operating gear may be wrecked. In case of stiffness in the engine that cannot be located immediately, have a careful examination made to see if the valves are getting oil.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER IV

Why valves are necessary.

The effect of their design on the speed of the car.

Why small valves are inefficient.

What happens when the engine is speeded up.

Why 16 and 24 valves are used in some engines.

Why valve timing is not a job for an amateur.

How lifters are adjusted.

Why valves should be adjusted when hot.

How to make the valve stem true.

Why valves need grinding.

The best way to grind valves.

How to test valves for a perfect fit.

What to do if the valve is in a very bad condition.

What adjustments are necessary after grinding.

The effect of worn valve stem.

How to repair worn rollers.

How sleeve valves work.

CHAPTER V

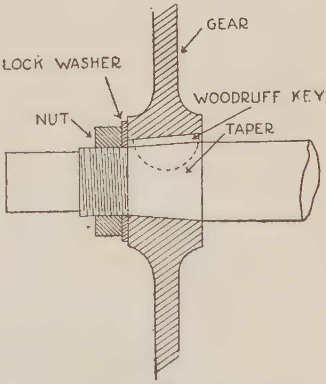
TIMING GEARS AND CHAINS

What Timing Gears Are.

The business of the timing gears is to drive the camshaft carrying the cams which actuate the valves. As the valves of a given cylinder open and close at every other revolution of the crankshaft, it follows that the camshaft must be driven at exactly half the speed of the crankshaft. This is accomplished by making the driving gear, on the crankshaft, precisely half the size of the driven gear on the camshaft.

In some cases the camshaft is at such a distance from the crankshaft that if only two gears were used they would have to be of such large diameter as to occupy an awkward amount of space. To obviate this three gears sometimes are used—a small gear on the crankshaft, a gear of twice the size on the camshaft, as before, and an intermediate gear large enough to drive from one to the other. The size of the intermediate gear does not matter in the least, so far as the relative speeds of the crankshaft and camshaft are concerned. As long as these two gears are in the ratio of two to one the intermediate gear may be two inches or two feet in diameter without making any difference. So the intermediate gear is made of whatever size will best suit the design of the front end of the engine.

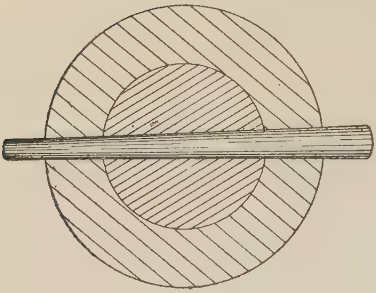
The use of an intermediate gear causes the camshaft to be turned in the opposite direction to that in which it would turn if driven direct from the crankshaft gear which, however, makes no difference so far as the operation of the cams is concerned.



HOLDING THE GEAR IN PLACE
The gear is forced on its tapered hub over the key and is held by a nut and lock washer.

How Gears are Mounted on Shafts.

Timing gears are secured to their respective shafts in a variety of ways. One way is to bolt the gears to flanges formed on the shafts. Another is to taper the hole in the gear, taper the seat of the gear on the shaft, fit a key to prevent the gear from turning on the shaft and provide a nut on the shaft to press the gear tight on the taper seat and key.



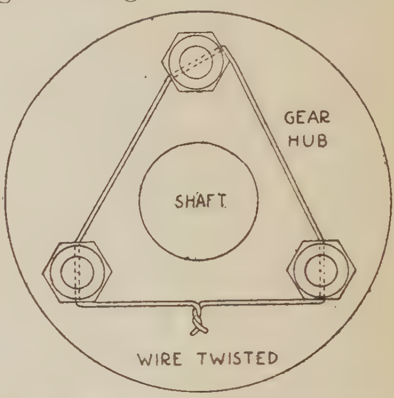
A TAPERED PIN

This is driven through an opening of corresponding size in the gear hub and shaft. The taper produces a wedge action which holds it in place.

Still another is to simply make the gear a good fit on the shaft and drive a tapered pin into a tapered hole running through both sides of the gear hub and the shaft.

Whatever method is used, the important thing is to be sure that the gear is held so that it cannot move on its shaft and that the nuts, screws or pins are so secured in their places that they cannot work loose.

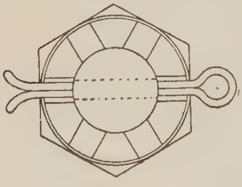
It may be emphasized here that there is no such thing as being too careful about locking bolts, nuts and the like in their places. The intermittent and often heavy strains, the constant vibration and even the changes of temperature, ranging from very cold to very hot, all tend to cause looseness. It may look, to the inexperienced man, like an excess of caution when screws or nuts are provided with lock-washers and then with wire passed through holes drilled in all the heads, or with lock-washers and castellated nuts with split-pins. It is not an excess, however. Lock-washers often break and fail to hold. Split-pins sometimes fall out. But a double lock is practically immune from trouble, and immunity from trouble of this kind is absolutely necessary.

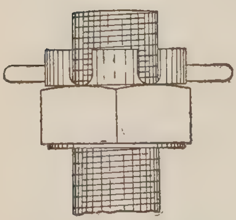


HOLDING THREE NUTS IN PLACE

A wire is passed through holes drilled through all three nuts and their shafts, and is then twisted so that none can turn.

Where the fastenings are bolts or screws and one of them becomes loose and backs out, it may not affect the security of the gear itself, for if there are, say, two others they will hold well enough in all probability. But the projecting screw may strike against some other part, or it may scrape against the housing and gradually cut through it—which has happened many times. If the screw strikes anything something has to break or bend. If it falls out it may, and probably will, wreck the gears.





CASTELLATED NUT

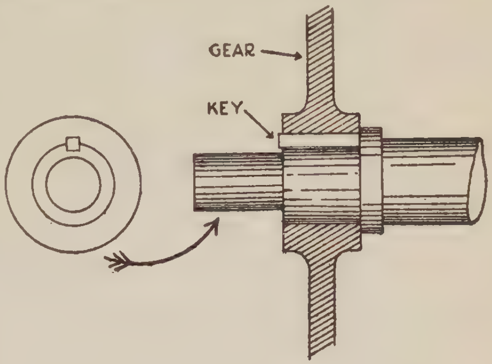
Slots cut in the top of this register with the hole in the bolt so that a cotter pin may be passed through both.

Taper pins may work out of place unless the small end is slightly riveted over. They must always be tightly driven, and the holes accurately lined up.

a shaft nut holding a gear on a taper seat must be well tightened and locked. If it backs off the gear will back off too and, if there is room, will continue to back off until it gets out of mesh, or it may continue to operate half off, allowing much back-lash, which seriously affects the valve timing. At the same time the teeth will wear rapidly and unevenly.

Types of Keys.

There are two types of keys in common use, the plain square-section key and the Woodruff. The ordinary plain key is simply a piece of square steel fitting accurately and tightly in two grooves, one in the shaft and the other in the hub of the gear, the two, when brought together, forming an opening of exactly the size and shape of the key. The opening into which the key goes is called the key-seat or keyway.

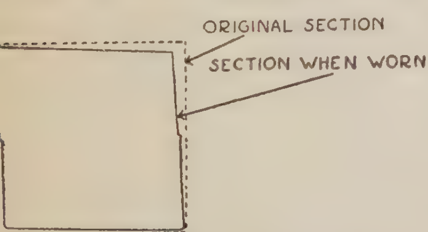


A PLAIN KEY
Half of the key is placed in the slot in the shaft and half in a recess cut in the hub; this causes the shaft and hub to turn as a unit.

The Woodruff key is semicircular—half of a steel disc. Its key-seat in the shaft is of the same arc shape as the key, and the round part of the key fits it exactly, leaving the straight edge projecting as much as is necessary to hold the gear properly. Once in its place the Woodruff key cannot work out. Because of its semi-circular shape it can rock in its seat in the shaft so that, as the gear is forced into place, it adjusts itself to the key-seat in the gear hub.

How Keys and Key-seats Wear.

A well-fitted key of sufficient size to stand the strains to which it is subjected shows very little wear. As a matter of fact it should show none. The fact is, however, that keys sometimes do show wear. Usually it is because of loose fitting, which permits hammering, or because of inaccurate fitting, so that one part of the key takes all the strain. The key becomes worn on the surfaces under pressure, and the wear allows it to



WHAT HAPPENS WHEN THE KEY WEARS
The wear occurs on the sides where the power is applied and where the resistance is overcome. Looseness rapidly induces additional looseness; hence, the key should always be kept tight.

tilt a little, and this not only distorts the key itself, but the key-seats as well, so that they become enlarged at the edges and lose their squareness. Ordinary keys are more subject to trouble of this kind than the Woodruff type because of the deep seat of the latter in the shaft holding it up and tending to prevent tilting.

Refitting Keys.

When a key is found to be worn there is absolutely no use trying to make it do further service. A new key must be made and fitted to the key-seats.

The mere fact that a key is tight in its place does not indicate that it will give good service. It must be reasonably tight, but the important thing is to have it bear evenly on all sides of the key-seats. It is a common thing to see a man hammer a key out of shape to make it a tight fit. A key "fitted" in this way will not give enough service to make it worth putting in. Don't do it, except, possibly, as a last resort in an emergency.

Fitting a key is not a very difficult job if the fitter will be content to go slowly and carefully and give free rein to his mechanical conscience—that is, the kind of conscience that will not be satisfied to let a poor job go through.

With a key of the ordinary type the first thing to do is to get a piece of steel a little larger than the original key to allow for the slight enlargement of the keyway due to squaring it up. Usually the key-seat will be widest at the top and narrowest at the bottom. The wear will not be the same on both sides, however, for naturally the side against which the pressure comes will get the worst of it. The keyway in the shaft will be most worn on the side opposite to that which gets the most wear in the keyway in the hub.

Material for Keys.

Finished square steel suitable for making keys can be obtained at large hardware stores. If this is unobtainable square tool steel will do very well, provided the proper size can be had. It will pay to take a good deal of trouble to get the right size of steel, for making a key from stock that has to be much reduced in size is not easy for the tyro—that is, the making of a really good key.

Square up the keyway with a smooth-cut file. The sides of the keyway must be parallel and at right angles with the bottom. This is where care in the work is necessary. The new key is used as a gauge. It must touch for its full length on both sides, and rest squarely on the bottom of the seat.

Take the greatest pains to make the sides of the keyway parallel.

It is very easy to file a little more off the ends than the middle, or more off one end than the other, and this must be avoided.

If you find that the key fits at one end of the keyway, but will not enter at the middle, tilt your file so as to take off metal at the tight place without touching the part where the key already fits.

ROUND OFF THE KEY CORNERS
Make the corners of the keyway as square as possible so that the key may be forced to the bottom.

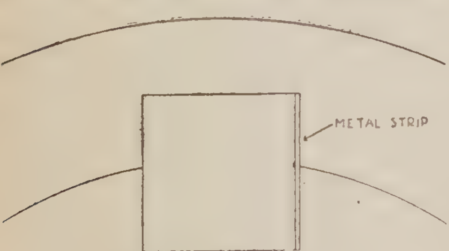
Get the corners of the keyway cleaned out as sharply as possible. Even then it is probable that the corners of the key will be even sharper so that the key cannot go all the way to the bottom. Round off the key corners very slightly—just enough to let the key down, and no more.

Get the key right down on the bottom of the keyway.

Fit the key into the shaft first. Leave it half an inch or so too long and taper the projecting end so that it is a little smaller than the old keyway. Put the key in place in the shaft. It should go in a light driving fit. Drive it in lengthwise and send it to the bottom with a block of wood between it and the hammer.

The Gear Hub.

Start squaring up the keyway in the gear hub, but do not at first take off as much as in fitting the key in the shaft. Do the final fitting by slipping the gear into place and sliding it as far as it will go over the key. Put Prussian blue, or red lead or any other kind of marking on the key and it will show where to remove metal in the keyway in the hub. The key will be found, in all probability, too high. It will be better to file off the top of the key to fit the bottom of the hub keyway than to file the latter. Don't forget the slight rounding of the corners in doing this. The sides must fit just as in the shaft keyway. Neglecting the corners may make you think the key is fitting tightly when really only the corners are holding it and making it bind. The last part of the job is to trim off the projecting end of the key.



TIGHTENING AN OLD KEY
Place a strip of copper or brass between the key and the sides of its seat to take up the wear.

Temporary Key Tightening.

In case a key needs refitting and new steel cannot be obtained at the time a fair job can be done by squaring up the keyways and the old

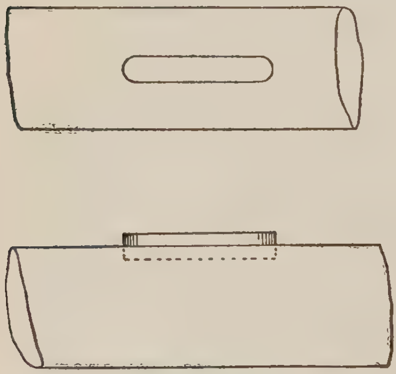
key and filling the space with a strip of thin metal of the same size as one side of the key. In such a case it is necessary only to use the sheet metal at one side. Hard brass can be used. This is distinctly a temporary job. It is better, however, to do a temporary job than to let a gear run loose on its key.

Refitting Woodruff Key.

Woodruff keys rarely show wear in the shaft key-seat. If there is wear in the hub key-seat and the corresponding part of the key it can be taken up, as a temporary expedient, by using a slip of sheet metal, as described. While keys are made in a wide range of sizes and are easily obtained, a new key can be made by sawing a section from a round bar of steel of the proper diameter and filing it to fit. The trouble with this kind of a job is that while the deep part of the keyway remains its original width the hub part is likely to be larger. If you are possessed of a little skill with tools you can make the new key thicker above the shaft than in it, and so fit it to both seats. Otherwise it is a job for the repairman. It may be said, however, that these keys are not often found in trouble.

Other Forms of Keys.

When it is necessary to use a key on a plain shaft at such a place that the keyway cannot be run to the end of the shaft the key is "let in," a seat being cut the exact length of the key and the key fitted into it; usually the ends are round.

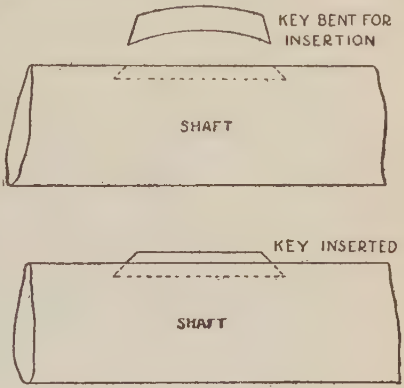


A "LET-IN" KEY
The corners are rounded and the key must be put in so that it will stay in place.

Sometimes it is desirable to fit a "let-in" key so that it will remain firmly fixed in position. This can be done very effectively by making a key with the ends beveled, undercutting the ends of the keyway in the shaft to the same angle, bending the key until it is shortened sufficiently to go in and then straightening it out in place with a hammer, forcing the beveled ends into the undercuttings.

In making and fitting such a key it is necessary to work with a good deal of care. The first operation is to undercut the ends of the keyway. It would be extremely difficult to do this with absolute accuracy and it is not necessary that it should be a perfect job. But the angle should correspond as nearly as possible with that of the key. A sharp, nar-

row cold chisel—the same width as the keyway—should be used. Care must be taken to see that there will be room for the key when it is straightened out in its place. Otherwise it could not be straightened. If the key is shorter than the keyway it cannot be made tight. This is simply a matter of careful measurement, however, and is not difficult.



INSERTING A "DOVETAIL" KEY
This is a solid and substantial design and is easily made and inserted.

When the key is set in for straightening, hammer it down with a piece of soft brass or copper as a buffer. Inevitably the key will be somewhat crooked on top, and for this reason it must be left a little high so that it can be trimmed down and subsequently properly fitted in the other key-seat. Soft steel must be used for this work. Tool steel or any hard, springy steel will not answer because it will not bend easily enough and cannot be properly hammered out straight.

Once the key has reached bottom, which can be detected by the feel of the hammer, stop hammering. Use a few fairly heavy blows rather than many light blows, the straightening is better effected in this way.

Occasionally a key is used that is tapered and driven into place in a tapered seat. Such a key usually has a head which makes its removal possible. If the key is not very tight it can often be pried out by inserting a steel bar under the head. If it is tight it can usually be persuaded to come out by using a hammer on the long end of the bar. If there are openings in the web of the keyed wheel, or if it has spokes, a bar can be rested against the head and a hammer applied, and this is the easiest way to do the job. Fitting a new key in a tapered seat requires nothing more than patience in driving the key in a little to mark it, removing it and filing, trying again and so on until a good fit is obtained. Be careful not to drive hard. In the early stages the outer end of the keyway will be enlarged by too much force. Press the key in by hand until it gets so much bearing that this does not give plain marks. Then drive only very lightly.

Timing Gear Wear.

The chief result of timing gear wear is noise, and timing gears are capable of making a good deal of noise if they are badly worn. Excessive wear will of course affect the valve timing, but with the good gears commonly used in modern cars sufficient wear to throw the valves out

appreciably rarely occurs. If gears are badly worn there is nothing to do but replace them.

Replacing Timing Gears.

In putting in a new set of timing gears the important consideration is to make sure that the timing is not altered—that is, that the relative positions of the crankshaft and the camshaft are preserved absolutely.

Leave the old gears in position until the new gears are at hand. Secure the crankshaft and camshaft so they cannot move while the change is being made. Just how this is done will depend upon the construction of the engine. If the flywheel is exposed it can be lightly wedged so that it cannot turn. The camshaft is likely to be moved, as soon as the gears are unmeshed, by the pressure of the valve springs acting on the cams through the lifters, so do not remove the gears until the camshaft has been blocked.

The new gears will probably go into place a little stiffly, and care will have to be used not to move the shafts in getting them on.

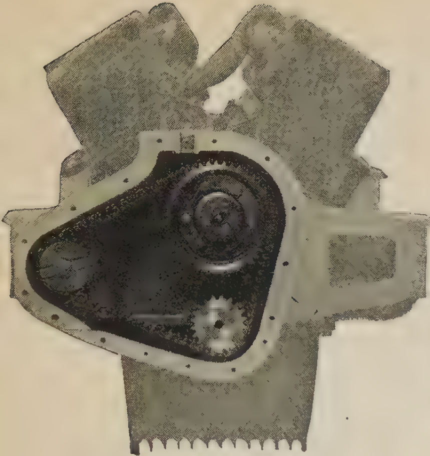
If the new gears are marked for meshing, disregard the marks at first. Put them on with the engine just as it was, and when they are on see if the marks come together properly. In all probability they will. It is easier to do this than to try to get the shafts into the right position first.

If the gears are marked and instructions are given to put them with the marks coming together with the flywheel in a certain position, determined by the marks on its rim, set the flywheel properly and then block it and the camshaft. The gear marks should then come together.

How Chains are Used.

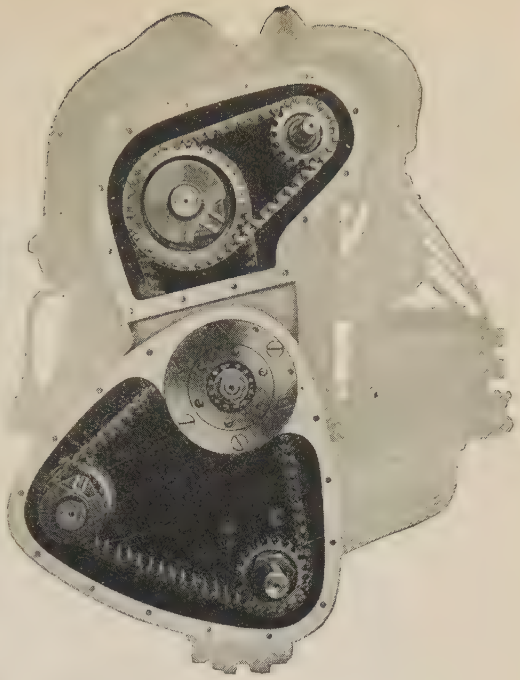
In many cars the camshaft is driven by a chain of the silent type instead of by gears. Chain drive has the advantage that it is practically noiseless, when the chain is properly adjusted, and even when it is somewhat loose it is quieter than slightly worn gears. A common practice is to use the same chain that drives the camshaft to drive the auxiliary shaft—that is, the shaft carrying the generator, pump and so on—running the chain over three sprockets and forming what is called a triangular drive.

Chains always ''stretch'' and the stretching is most rapid in a new chain. As a rule the chain requires adjustment after about 1,000 miles in a new car, and thereafter at considerably longer intervals. In some cases the camshaft is driven by gears and the auxiliary shaft by chain. Sometimes there are two chains.



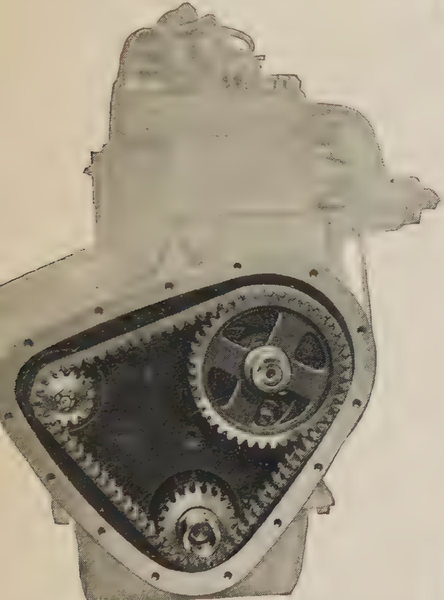
EIGHT-CYLINDER TYPE

The single large cam-shaft gear operates all 16 valves.

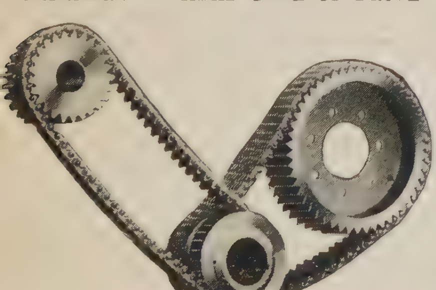


THE OVERHEAD CAM-SHAFT TYPE

The height of the cam-shaft above the crank-shaft makes the use of two chains better than one long chain.

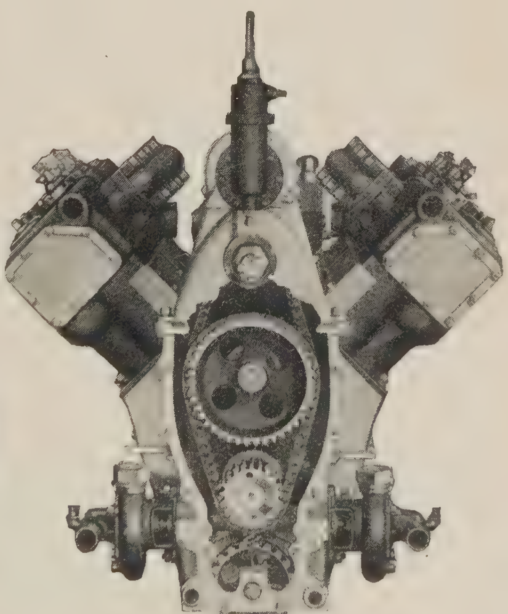


ORDINARY "L"-HEAD TYPE OF DRIVE



WHY THE CHAIN IS SILENT

Each link is composed of half a dozen or so of thin sections which enables each "tooth" to adjust itself automatically to wear in the gear.



EIGHT CYLINDER TYPE OF DRIVE

The cam-shaft is driven by the large central gear from which a chain extends to the pump and timer shaft.

Methods of adjustment differ in different cars. Your instruction book will tell how your chain is adjusted, if you have one.

A chain that is too loose will have a slight rattle, and if it runs close to the housing it may slap against it. The effect on the timing is the same as in the case of loose gears. In some cars the adjustment of the chain does not affect the timing; in others it does. Refer to the instruction book or the service station.

Even if a loose chain is not particularly noisy it should be adjusted, for there is considerable danger that the intermittent strains may cause it to break.

In adjusting a chain take care that it is not made too tight. Too tight a chain will make a humming noise with a grind in it. It is hard on itself and on the bearings.

When a chain is so worn that it cannot be taken up any more it is sometimes shortened by putting in what is called a ''hunting'' section. This is a short section containing one link less than the section removed. Better let the repairman do this, as it is rather a delicate job and must be done just right.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER V

What timing gears are.

Why intermediate gears are used.

How gears are mounted on shafts.

Why the fastenings must be positive.

What may happen if screws or bolts loosen.

What may happen if a gear gets loose.

What a plain key is.

What a Woodruff key is.

What other kinds of keys are used.

How keys and keyseats wear.

How to fit a new plain key.

How to make a temporary key fit.

How to fit a worn Woodruff key.

What kind of steel to use for keys.

How to square up worn keyways.

How to fit taper keys.

How to make a dovetailed key.

How to remove a headed key.

What happens when timing gears wear.

How to replace a set of timing gears.

How chains are used for camshaft drive.

What a triangular drive is.

Why chains are advantageous.

How chains wear and stretch.

What happens if the chain is too loose.

What happens if the chain is too tight.

What to do when a chain cannot be adjusted any more.

CHAPTER VI

IGNITION

Little Things Important in Ignition.

In the ignition system, more than in any other part of the car, small matters and minute adjustments are vital. Not that close adjustment is not important in other things besides ignition, but whereas, for instance, the carburetor can be considerably out of adjustment and yet the engine will run passably, any considerable lack of ignition adjustment will bring everything to a stop. The fundamental reason is that the range of adjustment is very small, being measured in hundredths and even thousandths of an inch. Small though such spaces are, they are sufficient to make a vast difference. An infinitesimal gap will effectually stop the flow of a low-tension current. A generator brush that misses making contact with the commutator by a hair's breadth will put the whole system out of order. A very few hundredths of an inch in a spark-plug gap will make the difference between regular firing and regular missing. And so on. Keeping the ignition system in proper condition is a matter of small attentions. Almost invariably the bigger things take care of themselves.

Direction of Adjustment.

If an ordinary adjustment is required, for which convenient provision has been made, there are two vital points to be remembered. *First, as has been stated, the amount of adjustment will be very small. The second point is that the normal wear which calls for adjustment takes place in a certain definite direction, and the adjusting means are designed to follow up this wear. So find out first of all in what direction your adjustment is to be made, and follow it up in the proper way and a very little at a time.*

There is a substantial reason for this. If your adjustment is out a hundredth of an inch, and you go to work and turn your screw, or whatever it may be, in the wrong direction, you are completely at sea, for you have altogether lost the original adjustment and, having done this, it will be all the more troublesome to get things right.

On the other hand, if you know positively the direction of wear, and therefore the direction in which you must make the adjustment, you can proceed until you obtain results and you will not have the feeling

that you are groping around in the dark and that you may hit it or you may not. And if you do not, you will not know why.

All this may seem too simple and elementary. In fact, it is simple and elementary. That, however, is just the reason why it is vital.

It is a fact that nine-tenths of the troubles that beset car owners, so far as ignition is concerned (to say nothing of other matters) could be avoided by a rooted appreciation of these principles and the use of common sense in their application.

Principles More Important Than Details.

All ignition systems are alike in many respects. The whole object is to cause a current of electricity to jump from one spark-plug electrode to the other. This calls for a current of high tension, and high tension, to all intents and purposes, means simply high pressure, for a low-pressure current will not jump the gap. Of course, even a high-pressure or high-tension current has its limitations, and will not jump if the gap is too wide, just as a man cannot jump a ditch if it is too wide for his leaping ability.

At this point the question may be asked: Why not provide a current of such intensity that it could jump any gap?

Limits to Intensity of Current.

It is true that it would be a very simple matter to generate such a current; there would be no difficulty in that score. But there are two reasons why it would be impracticable. In the first place the heavy current would burn away the spark-plug points, and the plugs, no matter how well made, would soon go out of business. In the second place high-tension current is difficult to confine. It will find its way through the most efficient insulation that can be used. If you want proof—and have not already had it through sundry electrical jolts—take hold of a high-tension wire and lay the other hand on the engine or the frame of the car when the engine is running. The fact that the current is exceedingly difficult to confine will be conclusively and painfully demonstrated, for it will pass instantly through the heavy covering of the wire—a hundredth part of that covering would stop a low-tension current—and pass through your body, which is itself a fairly good insulator.

Increase the pressure of the current to any considerable extent and it would be a constant source of trouble from leakage. It would involve insulation of impracticable thickness and weight, the wide separation of all parts carrying the current, and would add much to the bulk and weight of the whole system. Dampness would make untold trou-

ble, for the slightest moisture forms an easy path for a high-tension current. In short, higher tensions than are now used are out of the question, in the existing state of the art. So it is necessary to strike a workable medium, using a current of as high a pressure as can be carried without undue leakage and of as low intensity as will jump the spark-plug gap and give a sufficiently hot spark.

Why Care is Needed in High-tension Insulation.

The extreme ease with which high-tension current will escape makes it essential that all conductors carrying it be of the best to begin with, and kept in the best condition all the time. Cheap high-tension cable is not worth a thought. Not only is its insulating capacity low, but it is readily affected by moisture and oil, either of which will greatly facilitate leakage. And so far as cost is concerned, the difference in price is so slight as to be insignificant. The covering or insulation must be preserved carefully. The combination of high temperature and oil is a hard one to resist, even for the best cable, and therefore all high-tension conductors should be so placed that they will be as far as possible from hot parts of the engine and protected from oil. Kinks in the cable will lead to defects in the covering, and when such a defect occurs leakage is simply a matter of an easily-found opportunity.

Covering a bad place in a high-tension cable with friction tape does very little good, for friction tape is but a poor insulator for high-tension current. A contrary opinion is common, but it is wrong.

A high-tension cable resting on any part of the engine is likely to cause missing, because it is sometimes easier for the current to jump from the wire, through the covering, to the engine than to jump across the gap of the plug.

And an electric current will invariably choose the easiest way. This fact lies at the bottom of all electrical work.

Sources of High-tension Current.

High-tension current is obtained in two ways. The method by which it is obtained governs the general type of the ignition apparatus. By one system low-tension current from a battery is converted into high-tension current. By the other high-tension current is generated directly.

The first system is used in cars having no magneto. The second involves a magneto.

In the first system the common practice is to take current from the engine-driven generator or dynamo and store it in the storage battery for use as it is needed. There are variations in detail. Sometimes

current for ignition is always taken from the storage battery. Sometimes current is taken from the battery at first, and from the generator or dynamo as soon as it acquires sufficient speed, an automatic device making the change in the circuits. Sometimes a set of dry cells is used to furnish the initial current and the generator takes up the work when the engine is started. Your instruction book will tell you what method is used in your system.

THE IGNITION COIL
This is used on all battery ignition cars.

In any case, low-tension current is supplied by the storage battery, the dry battery or the generator. This current is passed through a transforming coil and comes out in the form of high-tension current.

Essentially the coil is simple. It consists of a coil of a few layers of comparatively heavy wire, the two ends of the coil being connected to the battery or generator leads, as the case may be. This is the primary winding. On top of the primary winding is another winding of a great many layers of very fine wire, both ends of this coil, which is called the secondary winding, being connected to the spark plug circuit. The wire of the primary winding is not connected with the wire of the secondary winding.

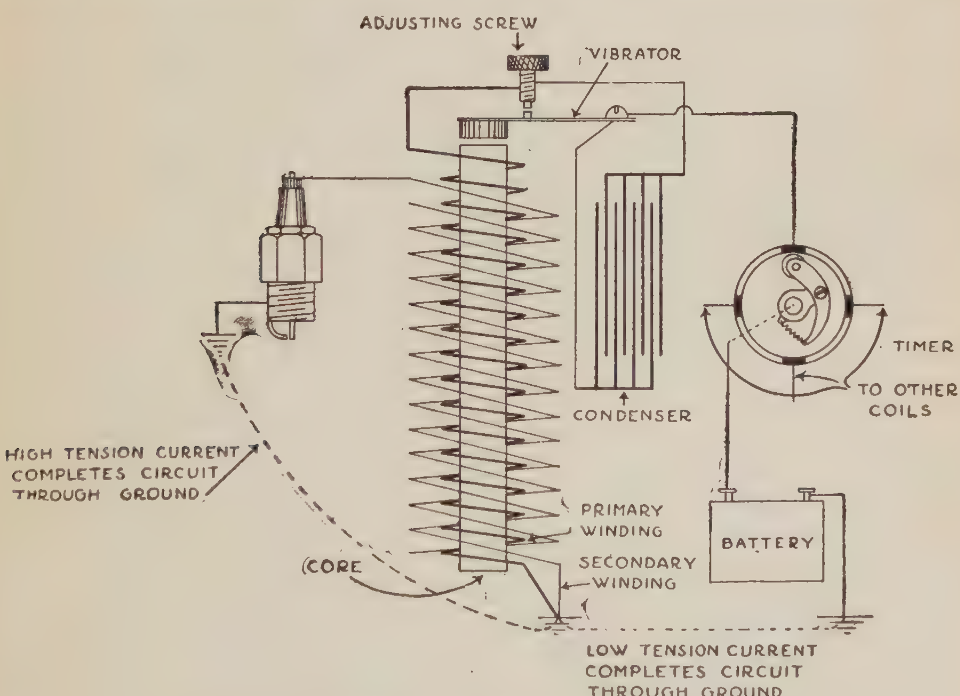


DIAGRAM SHOWING THE CONSTRUCTION OF A COIL

There is no connection between the primary winding from the battery and the secondary or high tension winding, leading to the plug. The high tension current is "induced," hence, the name "induction" coil, often applied to this electrical device.

But it is property of electricity that a current passing through a wire will cause a "secondary" current to be generated or "induced" in another wire running parallel with the first, and the intensity of the secondary current is governed by the relative lengths and sizes of the windings.

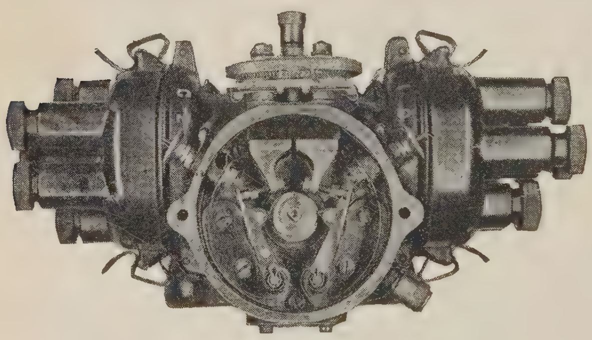
A low-tension current passing through a short length of heavy wire will generate or induce a high-tension current if the secondary winding is of a great length of fine wire. This is the condition that obtains in the ordinary transformer coil. The reverse also is true; a high-tension current is "stepped down" by reversing the arrangement, but this is not a point that comes up in this connection.

Timer and Distributer.

It is not necessary that current should be kept constantly flowing through the primary coil. In fact, if it were there would be such a drain on the battery that it would soon be exhausted. So the current is allowed to flow only at the instant the spark is required.

The low-tension current is sent into the coil by the timer or interrupter or contact-maker, as it is variously called. Incidentally, this device is very often called the commutator.

The high-tension current from the secondary winding is led to the distributer, the sole purpose of which is to conduct the current, when produced in the coil, to the spark plugs in the proper order. The distributer has a rotating arm, or its equivalent, which carries the current, and the arm passes successively over a series of conductors, each of which is connected to one of the cables leading to the spark plugs. The distributer is so set that the arm is in position to deliver current to a spark plug each time the timer closes the circuit and causes current to flow through the coil.



AN EIGHT-CYLINDER TIMER AND DISTRIBUTER

The two circuit breakers or contact points of the timer—one for each block of cylinders—are shown in the center. The projections at the side show the terminals of the distributor.

The distributer has nothing to do with the timing. This is all done by the timer. The business of the distributer is to be in such a position that it can convey the current to a plug when the current is sent through by the timer.

As the high-tension current can jump a small gap almost as easily as

it flows through an unbroken conductor, it is usual to make the distributer arm pass very close to the spark plug conductors without quite touching them. This eliminates the wear that would follow actual contact.

The timer and distributer work at precisely the same speed and must be synchronized. Therefore it is usual to combine them in one instrument, the same shaft carrying the timing device and the distributer arm. All that is necessary is to see that there is effective insulation between the conductors of the two sections.

Spark Advance and Retard.

If you touch a match to a candle it will take fire, burn dimly at first and gradually grow to a full flame. The same thing is true of the gas in the cylinder. When ignited by the spark, the gas takes fire immediately, but the full blast of combustion comes a little later. In other words, a little time elapses between the jumping of the spark and the attainment of the full pressure of the charge.

It is this delay or lag in combustion that makes necessary the advance and retard of the spark.

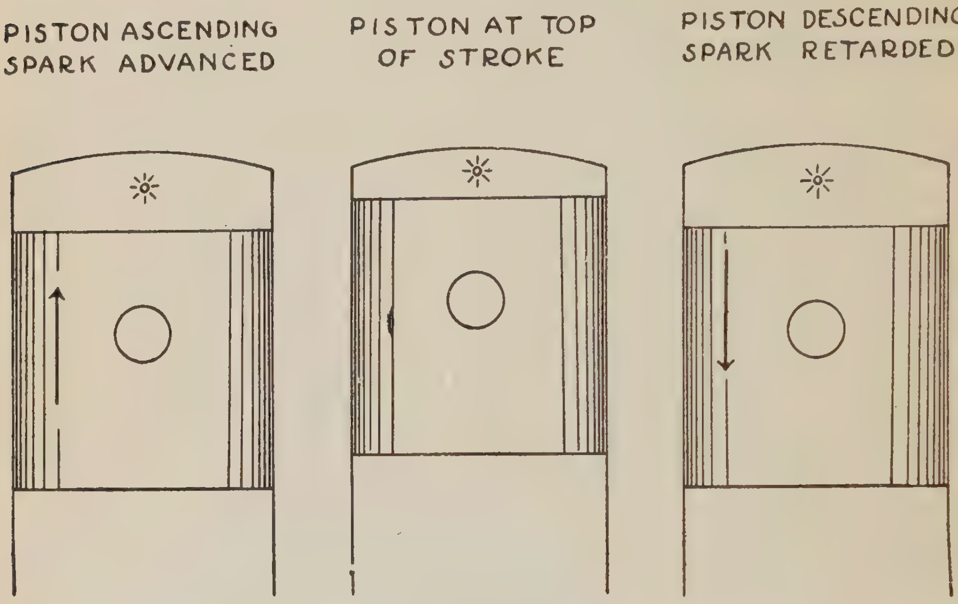
The best results are obtained when the charge reaches its highest pressure just as the piston has passed over the highest point in its stroke. If combustion was absolutely instantaneous there would be no need for timing the spark. It would be set to occur always at the top of the stroke. But with the engine running at its normal working speed ignition at top dead centre would mean that the piston would have time to travel through part of its downward stroke before the "explosion" had time to get up full strength. As a result, the maximum thrust would not be delivered at the most advantageous point in the stroke, and the charge would be allowed to escape through the exhaust valve while it still contained a good deal of energy that should have gone into pushing the piston.

So when the engine is speeded up the spark is advanced. That is, it is made to occur just a little before the piston reaches the top of its stroke, so that it is at its maximum strength just as the piston is starting to descend, delivers its thrust in the most efficient way and is as nearly as possible "used up" by the time the exhaust valve opens.

The faster the engine runs the more the spark has to be advanced. The reason is simple enough. The time required for a charge of a given "richness" to attain full pressure after ignition is practically fixed and unvarying. It always takes just about the same length of time, no matter how fast or how slow the engine runs. So if ignition occurs at the correct point with the engine running at, say, 1,000 revolu-

tions per minute, it will be too much retarded—that is, it will occur too late in the stroke—when the engine is run up to 2,000 revolutions per minute, for the piston will be moving at double the original speed and will travel through twice the distance while the charge is getting up pressure, and the maximum thrust will be given while the piston is, so to speak, running away from the pressure.

On the other hand, if ignition occurs too early—if the spark is too much advanced—the charge reaches full pressure before the piston fin-



WHAT HAPPENS WHEN THE SPARK IS CHANGED

The greatest pressure should occur just as the piston starts to descend. The combustion of the charge occupies a certain amount of time regardless of the engine speed and consequently the timer must be set so that the spark may occur in advance of the top in order to secure the most pressure at the beginning of the downward stroke.

ishes its upward stroke, and maximum pressure is exerted at a time when it tends to push the piston backwards. If the advance is excessive it will stop the engine by preventing the pistons from getting all the way up. The sudden pressure in the wrong direction, met by the effort of the engine in insisting upon turning in the right direction, gives rise to the well-known knock that follows too early a spark.

The principle of timing the ignition is well-illustrated by the shooting of a duck on the wing. You do not fire at the duck at the instant he is in line with your sights. You fire before he reaches that point so that there will be a time for your charge of shot to reach the point where you know the duck is going to be. The faster the duck is flying the more you "advance your ignition" because you know that it will

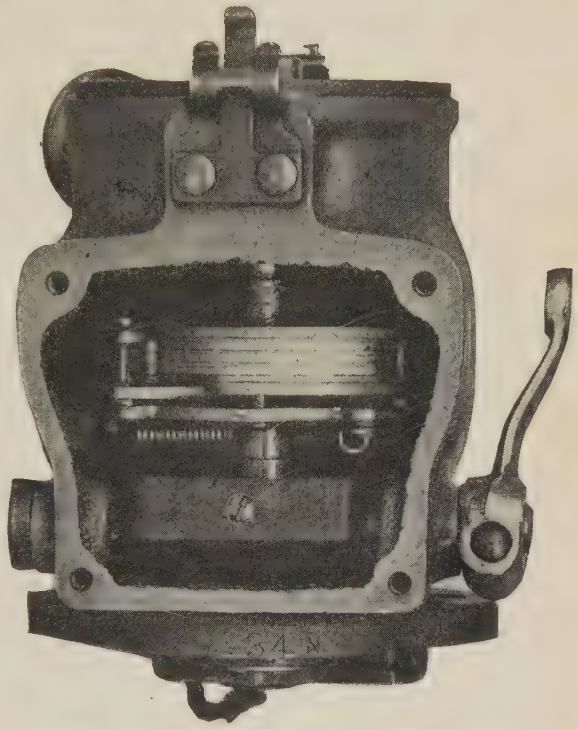
take just so long for the shot to travel the distance, and if the bird takes a shorter time to go through a given distance you must shoot a greater distance ahead of him.

So with ignition. The whole object is to hit the piston a full blow at a certain point in its travel, and the charge must be fired earlier or later, according to the time it will take the piston to reach that point.

Why Retarded Ignition Causes Heating.

It is a familiar fact that if the time of ignition is too late the engine will have a tendency to get too hot.

The heat of the burning charge is at its greatest intensity at the instant when the pressure also is at maximum. If this high temperature is reached after the piston has descended part way on its stroke there will be a considerable area of the cylinder walls exposed, and so a great deal of heat will be transferred through the cylinder walls to the water in the jackets, which will thus become abnormally hot. With a normally early spark maximum temperature is reached when there is very little cylinder wall area exposed to the heat. The temperature drops rapidly after reaching its peak and the cooling system is well able to carry off the heat. By the time the exhaust valve opens the charge is no longer burning. With a very late spark, however, the charge may be still burning when it is released, and this is exceedingly hard on the exhaust valves, increasing the tendency to warp and pit.



AUTOMATIC IGNITION TIMER

Many cars are now equipped with a device which automatically regulates the spark according to the speed of the engine. The fly-ball governor principle is employed.

Driving on a late spark, therefore, means loss of power, waste of fuel, overheating and exhaust valve deterioration, all in proportion to the error in the timing.

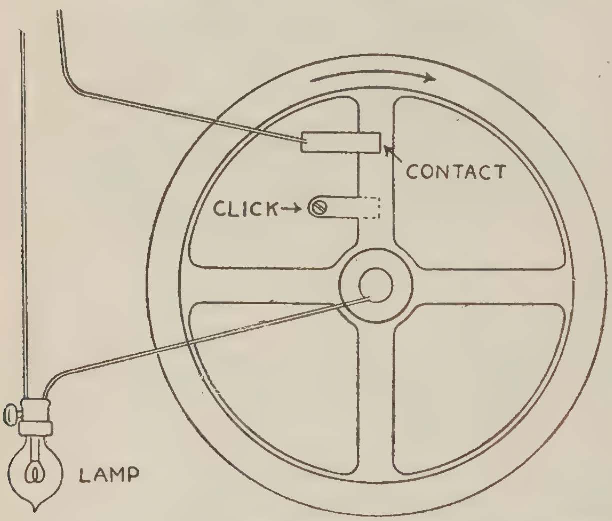
How to Control Ignition Time.

With the foregoing in mind it is not difficult to understand that driving "on the spark"—that is, controlling the speed of the engine by changing the time of ignition—is wrong. The speed should always be regulated by the throttle, and the ignition shifted until its time agrees with the engine speed. The proper timing is just short of the point where the engine begins to knock.

Driving on the spark is not good for the engine because advancing the spark without first opening the throttle causes knocking, and this is hard on all the bearings, subjecting them to sudden pressures that cause undue wear. Wrong handling of the ignition will cause an engine to wear more rapidly than it should.

How the Timer Works.

To illustrate the way in which a timer varies the time of ignition, suppose you have a metal wheel with four spokes turning slowly with a bit of flat spring or something fixed in a stationary position so that the spokes will strike it and make a click every time they pass. Also suppose you have a simple switch, made of two flat pieces of metal, attached to the ends of the two wires leading to an electric bell or an electric light, which you can hold so that the spokes of your wheel will bring the terminals together and ring the bell or light the light each time a spoke passes.



HOW TO ILLUSTRATE THE REASON FOR SPARK ADVANCE

The old-style carbon lamp reaches full illumination slowly—after the electrical contact has been made and broken, in fact.

Suppose the click represents the instant when the piston passes dead center at the top of its stroke, and you will have what will represent the running of a four-cylinder engine. And suppose that every time the bell rings or the light lights a charge of gas is ignited.

As the wheel turns, hold the switch so that the bell rings at the same instant the click comes. That gives you the spark just at the dead center. But if you move the switch around a little *opposite* to the direction of rotation of the wheel your bell will ring a little before the

click comes. That is advancing the spark. Move your switch around the other way—*with* the rotation of the wheel—and the bell will ring after the dead center click. That is retarding the spark.

Moving the timer against the direction of rotation of the timer shaft advances ignition. Moving the timer in the same direction as the rotation of the shaft retards ignition.

An Interesting Experiment.

If you actually rigged up such a demonstrating model—and it could be easily done—using an electric light, the principle of lag or delay in combustion could be very clearly shown, especially by using an old-style carbon-filament lamp. The lamp does not attain full brightness the instant the current is turned on, but requires an appreciable time to burn up.

With your wheel running slowly, hold the switch so that contact will be made at "dead center." The lamp will have time to burn up brightly before the wheel passes its clicking point. But, with the switch still in the same position, speed up the wheel, and it will be found that by the time the lamp has become fully bright the dead center will have been passed and the wheel will be well on its way. So to make the lamp burn at full intensity at the instant the click occurs you will have to move the switch around against the direction of rotation, and the faster the wheel runs the more you will have to move it.

Consider the lamp as the burning charge of gas and the instant of contact of your switch as the instant at which the spark occurs in the engine, and you will have actual conditions very closely paralleled.

The action of the distributer is so simple as not to require any such demonstration. All there is to it is to see that the arm is in a position to let the high-tension current pass to one of the spark-plug conductors every time the timer turns the current on. During the time the current is shut off by the timer the distributer arm is moving along to the next plug conductor.

Timer Construction.

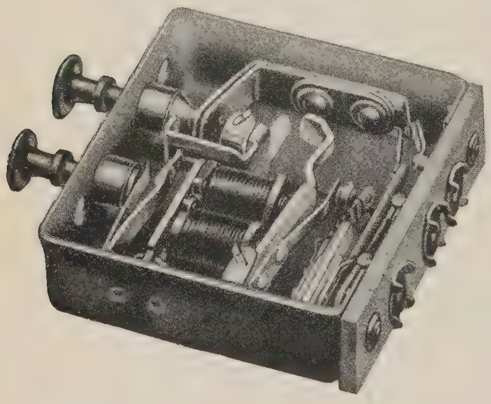
Timers vary greatly in constructional details, but all are alike in that one part can be swung part way around a circle so as to vary the timing, just as you swung around your little switch. Usually there is a swinging arm, the end of which makes contact with contact-pieces in the shell, the shell or body being the part that can be moved by the spark lever. The contact pieces are connected with outside connections to which the wires leading to the spark plugs are attached. As the shell is moved in changing the time, the wires have to move with

it, and so a certain amount of flexibility and play is necessary. This makes it important that the connections at the timer should be carefully made, so that the wires will not work loose.

To minimize wear the timer arm usually has a roller or a ball, in either case of hardened steel, at its end, and this is pressed against the contact pieces by a spring. Sometimes the contacts themselves consist of steel balls.

Instead of a swinging arm, many timers use a cam with as many lobes as there are cylinders to fire, the principle being much the same as that of the magneto breaker.

The single-spark timer or unisparker is so made as to be exceedingly economical of current, and it has the further advantage that it cannot stop with the contacts together, the result of which would be to permit the current to flow until the battery was exhausted. The rotating shaft has as many notches as there are cylinders to fire. A little trigger has a head which engages in these notches as they come around. The trigger is drawn forward by a notch, against the pull of a light spring, and then released. As the trigger flies back under the pull of the spring it strikes another member which closes the contact points for a very brief period. The contact is so brief and the action is so rapid that it is impossible for the eye to follow it, and when the timer is working, all the movement that can be seen is that of the trigger. The working parts are made of extremely hard steel and are subject to so little wear that it is negligible. The springs are very carefully calibrated and it is of the utmost importance that they be left precisely in their original condition. Never try to adjust or change anything in this timer except the contact points, which are provided with an adjustment of the usual type. Keep the timer clean—but look out for those springs. The distributer is built as a unit with the timer and requires no attention except to see that it is clean, the contacts are well made and that the little brush in the center is making good contact.

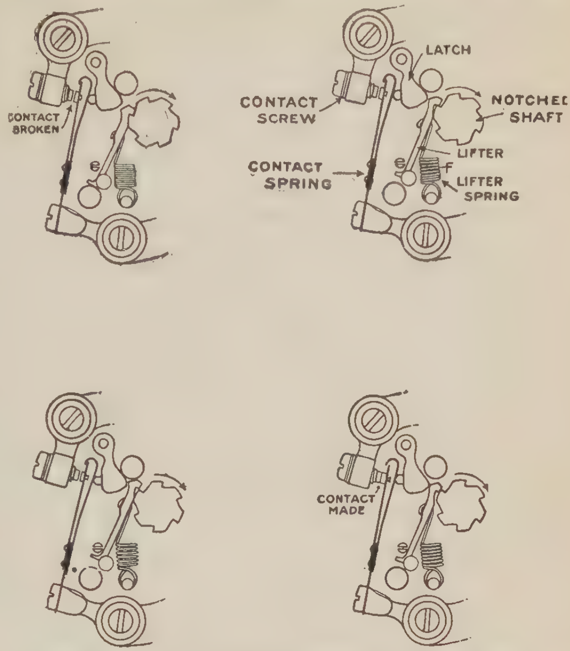


AUTOMATIC SWITCH

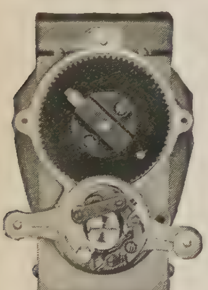
If the current is allowed to pass through the ignition system indefinitely, the spark-plug points may be melted. In this switch an electric heating element causes the contact to be broken whenever the current is left on beyond a certain limit.

The vital thing in a timer is to keep it perfectly clean. It carries low-tension current only, and it does not take much of an accumulation

of dirt to interfere seriously with the passage of the current and affect the accuracy of the timing. If there is enough foreign matter on the contacts the current may be prevented from flowing and there will be no spark at the plug. If there is enough foreign matter so that the current is merely delayed in getting through there may be irregular firing and inaccurate timing at low speed and more or less regular missing at higher speed because there is not time for the current to penetrate. So keep the timer perfectly clean. As for lubrication, requirements will differ according to the construction, and the instruction book must be consulted and heeded. There is nothing to wear in the distributer and nothing to get out of order, except the brush generally used to carry the current in. This is subject to very slight wear. Keep the distributer clean and see that the brush makes proper contact and it will give no trouble. As a matter of fact it is one of the least troublesome things on the whole car.



THE "OPEN CIRCUIT" SYSTEM OF IGNITION
The time of contact is practically instantaneous so that the current cannot continue to flow through the ignition circuit. This system was especially popular on some of the older types of cars.



THE HEART OF THE MAGNETO
The interrupter placed in the breaker box is simple, and this is the only part requiring attention for thousands of miles.

High-tension Magneto Principles.

The high-tension magneto is a complete ignition system in itself. It includes all the essentials of the parts that have been described. It has means for generating low-tension current, for transforming it to high-tension current, a timer and a distributer. The timer part, however, is called the interrupter or breaker because it works in the opposite way from the timer described in that it interrupts the low-tension current at the same point that the timer makes contact and turns the current on. The effect is precisely the same—that is, a spark is produced at the instant of interruption, just as it is in the other system at the instant of

making contact. The electrical principles involved are rather complex, and have little bearing on the ordinary care of the magneto.

Remember, however, that the spark is produced at the exact instant that the contacts separate and the low-tension current is interrupted. The time when the contacts come together again has nothing to do with the timing of the spark.

Interrupter Construction.

The interrupter is enclosed in a little housing at one end of the magneto, and a cover is provided that is readily removed, for this is the part that requires the most care and the most frequent inspection. However complex the interrupter may appear, it really is simple, and its complexity will vanish if it is studied a little while moving very slowly.

The interrupter is mounted on the magneto shaft and turns as part of the shaft. Essentially it consists of two contact points or buttons, usually of platinum, connected with the primary or low-tension winding. One of the points is stationary on its block while the other is pivoted so that it can be moved away from the stationary point. There is a projecting part, acting as a little lever, which may be an extension of the block or arm carrying the movable point or may be a separate lever acting on the member carrying the point, and as the interrupter rotates bodily this lever comes in contact with projections or cams formed on or attached to the inside of the housing. The effect of this is to move the lever and separate the points, which come together again as soon as the cam has been passed over. The number of cams depends upon the number of cylinders to be given ignition. A magneto for a four-cylinder car will have two, and so on.

The timing is varied on precisely the same principle as in the ordinary timer. The shell or housing carrying the cams is movable precisely as is the shell of the timer, and the effect is exactly the same.

Keeping the Interrupter in Order.

Keeping the interrupter working as it should involves three principal things—

Perfect cleanness of all the parts.

Accurate adjustment of the distance between the contact points.

Proper condition of the contacting faces of the platinum points.

Excessive oil can be removed by squirting a little gasoline into the interrupter with an oil-can. Let the gasoline dry away before running the magneto.

Don't dig around in the interrupter with a rag or waste. If you

want to remove something that will not loosen up with the application of gasoline, use a little bit of rag on a wire or a toothpick.

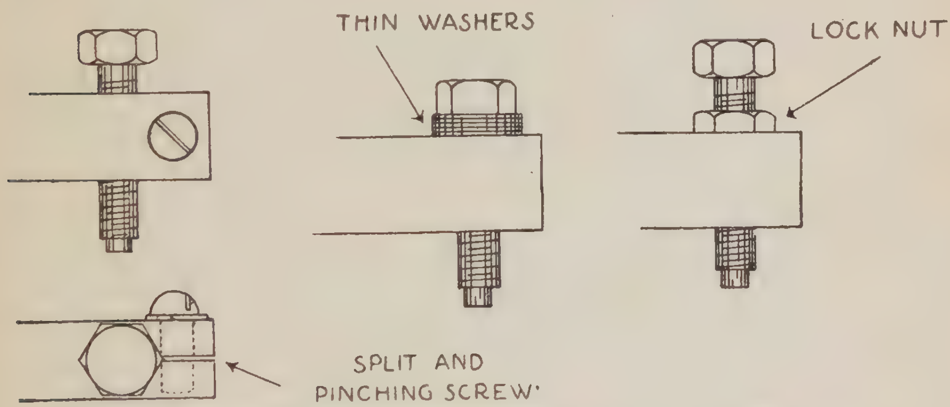
Oil on the contact points is an almost sure cause of missing fire. So when following directions for lubricating, it is best to be stingy with oil and perhaps apply it a little oftener, rather than be generous and slop it over places where it has no business to be.

The distance between the points when fully separated is so important that the magneto makers usually furnish a little gauge to make the setting accurate. This is merely a slip of steel of the proper thickness. The gauge should be used whenever there is any doubt on the subject.

Never set the points by guess. You can't guess accurately enough. Use the gauge.

The Importance of the Contact Points.

The contact points are little buttons of platinum perhaps an eighth of an inch in diameter. One of the points is mounted on the end of a screw by means of which it may be moved toward or away from the



METHODS OF HOLDING THE CONTACT POINTS IN PLACE

The adjustment between the contact points must be very accurate. Sometimes a hundredth of an inch will make a difference between perfect operation and annoying misfiring.

other point. The adjustable member is sometimes the moving and sometimes the stationary point. A glance at your magneto will show this. As it is of course vitally important that the point should remain in adjustment, the screw is provided with some locking means. There may be a lock-nut, or the screw may pass through a split block with a pinching-screw to draw down the split and clamp the screw, or there may be a number of very thin washers under the head of the screw, the removal of which, one at a time, will allow the screw to be turned

in further and advance the point. The screw, in this case, must always be tightened up hard against the washers.

Keeping the Contact Points in Order.

In time the platinum contact points become blackened and pitted from the action of the current. To do their work properly the points must be not only clean, but in contact all over their faces. Partial contact makes it harder for the current to pass from one point to the other and also greatly hastens the blackening and pitting and the wearing down of the platinum.

When the platinum points are no longer flat and clean they should be smoothed with a *very fine* file. The best tool for the purpose is a small flat jeweler's file, which can be obtained at almost any store where magneto supplies are carried. If the points require only a very little dressing the work can be done by the careful use of very fine sandpaper. Do not do this with the points in place in the breaker box, for particles of grit from the sandpaper are almost sure to get into the working parts and make trouble. Do not use emery cloth or paper. Emery is a conductor of electricity and has a habit of sticking rather tenaciously in places where it is not wanted.

After long service the points will wear away and require renewal. This is simply a matter of buying new points, screwing them into place, and setting them with the gauge. It involves only a little care and is not difficult to do.

Keeping the Interrupter In Place.

The interrupter as a whole is held in place on the magneto shaft by a screw at the center which is threaded into the shaft. See that this screw is always tight. If it becomes loose the timing will lose its accuracy and the firing will become erratic.

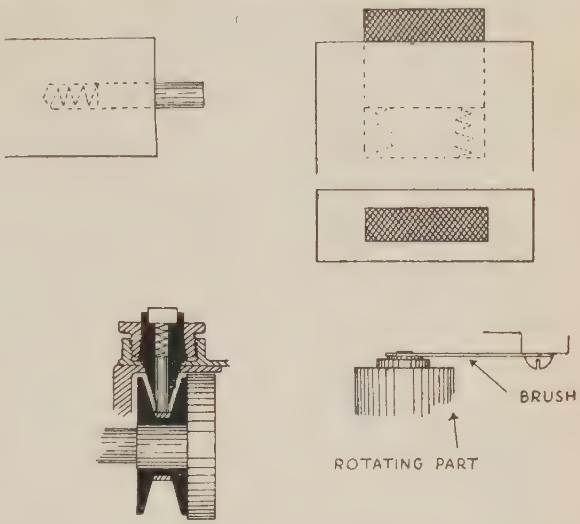
How to Care for Brushes.

Where current is carried from a stationary part to a revolving part brushes are used. Brushes are made of copper, copper gauze, carbon or graphite. In some cases a brush is simply a steel, brass or copper spring held against the center of a revolving part by its own light pressure. In other cases the bush is a separate member with a spring holding it against the rim of a rotating ring or "collector." The construction and location of brushes vary in different magnetos. See your instruction book.

A type of brush that is much used consists of a short rod of brass, copper or carbon, or a little block of carbon, setting in a recess in which

it is an easy sliding fit and pressed outward by a light coiled spring in the bottom of the hole. These brushes are sometimes so located that when other parts are removed the spring will shoot the brush out and it may be lost. Look out for this. Do not remove such brushes from their places if it can be avoided. The springs are rather delicate and often are so fitted that they cannot be removed without stretching them and so altering the tension.

Brushes require to be absolutely clean and free from oil, and to be pressed into contact lightly but firmly. A brush in good condition will produce a smooth, glossy surface of a dark color on the metal against which it works. Do not attempt to brighten up such a surface under the impression that it is dirty. A good working surface will give long service without attention and should be left undisturbed. Oil will quickly ruin it.



TYPES OF MAGNETO BRUSHES
Proper spring tension on these is important. They seldom require attention except frequent smoothing down or possible renewal.

How to Locate Magneto Trouble.

Ignition trouble does not by any means mean magneto trouble. Usually it is safe to suspect the magneto last. If, therefore, ignition is faulty make sure first that the magneto is not functioning properly before attempting to do anything to it.

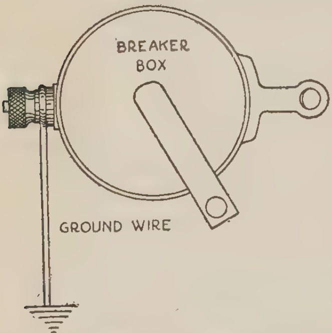
This is not difficult, as outside of the magneto there is nothing but the wiring and the plugs.

If ignition is irregular, or has ceased in one cylinder only, the trouble is not likely to be in the magneto, but rather in the plugs or the wiring leading the current to them from the magneto. The method of finding and correcting spark plug and wiring troubles is covered later in this chapter.

It is well to bear in mind, however, the fact that missing is not always due to the ignition system or any part of it. Leaky valves, worn stems which allow air to pass through, insufficient clearance between the end of the valve-stem and the lifter, poor carburetor adjustment,

leaking gaskets—all these things may cause missing in one or more cylinders though the ignition system may be working perfectly. Occasionally the design of a manifold is faulty, so that one or more cylinders may not be as well served with gas as others, and in such a case the missing is hard to remedy and sometimes can only be stopped by feeding a mixture that is too rich for the best running. This is a trouble that is not likely to occur, and is mentioned only as a possibility in cases where no other kind of trouble can be found to account for faulty ignition.

If the ignition fails suddenly and completely the most likely cause of trouble is in the ground wire or its connections. The ground wire is usually connected to a nut on the housing of the interrupter and runs to the switch which shuts off the ignition. Remove the ground wire from its connection on the housing and see if the magneto functions properly without it.



A MAGNETO GROUND WIRE

The only way that the ignition of the magneto-fired engine may be stopped is by turning the current to the "ground" so that it is not forced through the spark plugs.

To stop the engine by shutting off the ignition, in case the magneto runs properly with the ground wire removed, it will be necessary to replace the ground wire.

If the removal of the ground wire stops the trouble, look for poor insulation, permitting the current to pass to some other wire, or for bent, broken or dirty switch contacts.

Examine the distributer and see if it is clean, that it is free of oil and that the brush or brushes are in good order and the contacts clean. Brushes may be worn down, broken or improperly put in. Worn brushes, however, are not likely to cause sudden failure; they usually give warning by gradually increasing misfiring.

The Safety Gap.

Every magneto has a safety gap, the location of which is pointed out in the instruction book. This consists of a pair of points so connected up and at such a distance apart that the current will not jump them when the magneto is working under normal conditions. If, however, there is a break in the circuit so that there is no other escape for the current, it forces itself across the safety gap and so prevents the winding from being burned out by the high tension, or pressure. It is really the electrical equivalent of a safety-valve. The spark jumping the safety gap can readily be seen, and it makes a sharp crack that is unmistakable.

If current is jumping at the safety gap it indicates that there is a break in the circuit. There may be a broken spark-plug wire, or a wire disconnected from a plug, or the spark plug points may be burned away or so far apart that the current cannot jump across, or there may be a spark-plug wire disconnected at the distributer end.

In some magnetos the moving arm or lever in the interrupter is of fibre, and there may also be a fibre roller. In a new magneto the arm may be a little tight on its pivot, so that it works sluggishly instead of freely and with snap. The remedy is to very slightly enlarge the pivot hole. This must be done with great care, for only a very small amount of enlarging is needed. Squint through the hole to see if there is a little ridge at one end or the other that may cause binding. If so, its removal will probably be sufficient, without other enlargement of the hole. In very damp weather, or in case water has got into the breaker box, the fibre may be swelled and produce the same effect. A thorough drying out will probably remedy the trouble without enlarging the hole, and normal wear will be sufficient to prevent sticking after the magneto has been in service for a while.

Do not put any oil on fibre parts. They do not need lubrication, and oil will swell them.

If, after making these tests carefully, the trouble cannot be located, give the job to the repairman or to the magneto service station.

Weakened Magnets.

In time the magnets of a magneto become weakened, though it may be years before it will become noticeable, in the case of a good magneto. The result will be occasional missing at first, and this will increase as the car is used, being especially noticeable at low and moderate speeds. Sudden failure is not due to weakened magnets. The magneto service station, or a repairman who has the apparatus, can recharge the magnets so that they will be as good as ever. If recharging is necessary it is a good idea to have the whole magneto examined and put in good shape at the same time.

Never let an inexperienced or incompetent repairman fool with your magneto. It is an easy matter for an ignorant hand to make a great deal of trouble. Magneto work, outside the simple testing and adjusting described, calls for training, experience and skill.

Low-tension Magnetos.

Low-tension magnetos are not used to anything like the extent of high-tension magnetos. The low-tension magneto is simply a magneto that generates only low-tension current, having within itself no means of

raising that current to high tension. Therefore a separate coil is used, just as with a battery system or a system in which the current is furnished by the lighting generator.

The low-tension magneto has an interrupter of the same general type as the high-tension magneto, and its care will involve precisely the same points. In some cases the distributer is built into the magneto, as in the high-tension instrument, and sometimes it is not. In any case, the same principles of operation and care apply throughout.

Care of Coils.

As has already been explained, coils are used wherever the original current is a low-tension current and must be "stepped up" to the high tension necessary for the jumping of the spark plug gap. There are two general types of coils: one, which is now comparatively seldom used, having a vibrator or buzzer and the other having none.

Apart from the care and adjustment of the vibrator, where one is used, there is little to do in taking care of a coil except to see that all contacts are clean and firmly screwed down, that there are no stray strands of wire that can make short circuits and that the coil is kept dry, clean and as cool as possible. Dirty or loose connections are the only troubles that ordinarily occur.

With coils, as with all other electrical apparatus, it is absolutely essential to have the various wires connected to the right terminals. A single wrong connection will prevent the working of the whole system. So, if it is necessary to disconnect any wires, be positive that you can put them back in the right way before taking them off.

If you are not sure you can get the wires back to their proper terminals after they have been removed, do not experiment. The result may be a burned out or damaged coil. Do not imagine that if an ignition system using a coil does not work properly you can better it by using a higher voltage than that specified by the maker of the coil. Coils are made to give their best results at carefully determined voltages and an increase in the pressure may burn out the winding or, in the case of a vibrator coil, damage or even fuse the contact points.

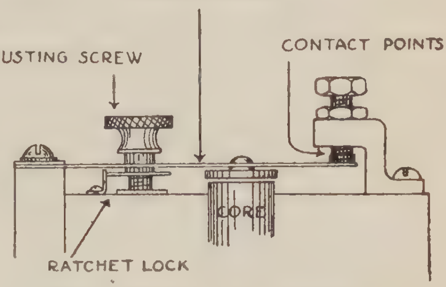
Vibrator Principles.

The vibrator of a coil works on exactly the same principle as the common electric bell and its purpose is to make and break the circuit hundreds of times a second; every time the circuit is made and broken a spark is produced, so that there is a rapid succession of sparks at the plug when the timer turns the current on.

A flat steel spring is fixed at one end and free to vibrate at the other; the free end carries a button of iron which is set so that it is directly

over the extended core of the coil. When current passes through the coil the button is attracted to the core and when the circuit is broken and the magnetic pull ceases the spring pulls the button away from the core.

The vibrator spring itself is the means of making and breaking the circuit. On the back of the spring is a contact point of platinum or other suitable metal and this, when the spring is at rest, touches a similar contact point mounted on the end of an adjusting screw. When the points are touching the current flows through the coil and when the points are separated the current is interrupted and does not flow through the coil.



THE VIBRATOR TYPE OF COIL

When the coil is magnetized by the current, the contact points are separated. This breaks the current and the spring returns again to the contact point. This serves to re-excite or magnetize the coil, and the operation is repeated thousands of times per second.

When the timer makes contact the current flows through the coil by way of the vibrator and instantly the spring is pulled down by the magnetic attraction. Pulling down the spring, however, immediately breaks the circuit, the spring flies back, the contact points come together again, the current instantly flows and the spring is again drawn down, and so on, the alternate attraction and release of the vibrator taking place so rapidly as to make the familiar buzzing sound. The adjusting screw is provided to adjust the distance between the soft iron button and the end of the coil core and to take up wear of the contact points.

Adjustment and Care of the Vibrator.

The adjustment of the vibrator is all-important in that it not only determines the quality of the spark, but also the consumption of current. If the adjustment is very loose—that is, if the screw is screwed out too far—the iron button will be so far from the core that it will be out of reach of the magnetic attraction, and there will be no buzz and the ignition system will not operate. As the screw is turned down the button comes within the influence of the pull and the vibrator begins to work sluggishly, with a slow, rattling sound. Turning the button down still further speeds up the vibration, and the vibrator sings a higher, steadier note. If the screw is still turned down the point will be reached where there is not room for the points to separate, and vibration will cease. In this case, however, current will continue to flow

and will be simply a waste and a drain on the battery if the timer should be on a contact.

The more the adjusting screw is turned down and the faster the vibrator works the better the spark will be, within certain limits. At the same time, however, the current consumption will increase. So the best adjustment is that which gives the best spark with the least current consumption.

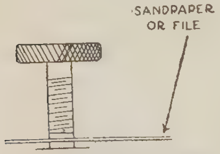
To adjust the vibrator, turn the engine until the timer is making a contact, making sure that the ignition switch is turned on. This will start the vibrator going. Loosen the adjusting screw until the vibrator stops buzzing. Then turn the screw the other way, tightening the adjustment, until the vibrator buzzes steadily. Start the engine. If it skips or misses, tighten up the adjusting screw until the missing ceases and the engine runs steadily at all speeds. Then lock the adjusting screw and leave it alone.

If it is desired to adjust the vibrator for the greatest spark efficiency, regardless of current consumption, the screw must be turned down a little further. The easiest way is to turn down the screw and note the effect while the engine is running. Up to a certain point the engine will continue to pick up speed as the screw is tightened. After the best running adjustment is found further screwing down only wastes more current.

Too tight an adjustment will cause the vibrator to stop working should the battery weaken or the supply of current in any way be reduced.

If there is a separate coil for each cylinder adjust one at a time. By holding down three of the vibrators or loosening the screws so there will be no buzz—in the case of a four-cylinder engine—the engine will run on one cylinder, that connected with the vibrator left free. Thus each vibrator can be adjusted separately.

The firing of any one cylinder can be tested in this way at any time and any missing due to the vibrator corrected readily.

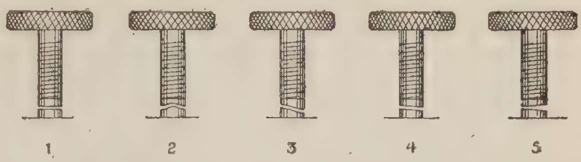


CLEANING THE CONTACT POINTS

A piece of sandpaper or a jeweler's file may be used.

With the vibrators adjusted as described there will be the least possible consumption of current. Should the battery become weak, however, it will be necessary to tighten the adjustment, for there will not be sufficient strength to move the vibrator at full speed and the engine will miss until the vibrator is readjusted. If, after having tightened the adjustment for a weak battery a new set of cells is installed or a storage battery recharged, the adjustment should be slackened to its original position to keep down the drain on the cells.

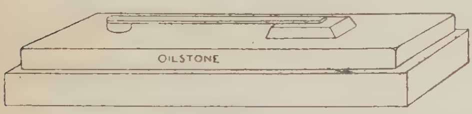
The contact points of the vibrator must be kept in good condition in precisely the same way as the contact points of the magneto. That is, they must be kept perfectly clean and the surfaces must make good, full contact all over. The dressing of blackened or pitted points is done with a jeweler's file. As there are no working parts liable to damage, however, it is safe to use very fine sandpaper for cleaning if filing is not needed.



HOW THE POINTS WEAR

No. 1 shows a properly-dressed surface; No. 2, a surface in which the current has travelled in only one direction; No. 3, a surface which, when the vibrator is turned, will cause only one small point of contact; No. 4, a surface which has not been properly dressed; No. 5, a surface touching only at the extreme edges.

Tungsten alloys are frequently used for contact points, and some of these alloys are so hard that they cannot be filed. They can be dressed, however, on an oil-stone. To keep the point in the proper position on the stone while rubbing it down, place a slip of wood or metal under the end of the spring opposite the point, taking care to have the slip of precisely the same thickness as the point.



DRESSING A VIBRATOR POINT

A fine whetstone should be used and a small piece of metal placed under the spring to give better contact.

Object of the Condenser.

The condenser is an important part of every coil and its business is to prevent flashing at the vibrator contact points. Without the condenser there would be a spark or ''arc'' which would play between the points each time they separated, and this would quickly burn away the metal. Further, the condenser adds materially to the efficiency of the coil, causing the spark to be bigger and hotter.

The use of too much current may break down the condenser, and occasionally—not often—the condenser fails from some defect. Failure of the condenser is indicated by sparking at the points, which blacken up very rapidly. If the engine misses, while the points blacken up soon after cleaning and there is excessive sparking at the vibrator contacts, when the proper current is supplied, it is reasonable to believe that the condenser has given out. The coil maker will have to put in a new one. The condenser is generally enclosed with the coil and sealed in and it is an expert's job to do anything with it. Occasionally, however, the condenser is placed outside, near the timer, entirely separate from the coil.

Grounding.

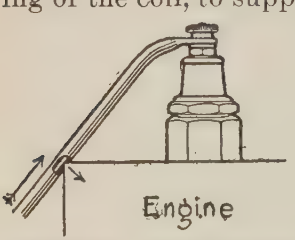
Grounding and ground wires are frequently referred to in connection with the electrical apparatus of a car, and the real meaning of the terms should be understood.

Electricity, in order to do work of any kind, must flow from its source, through the apparatus in which it does work—whether a coil, spark-plug or whatever it may be—and back to its source, forming a complete circuit. Any break in the circuit that the current cannot pass brings everything on that circuit to a stop.

It is necessary that the conductor, or the series of conductors, through which the current is led to its work, should be completely insulated from the return part of the circuit.

In the ignition circuits the current is led out from its source through wires, but instead of going back to its source by way of wires it goes through the metal of the engine and frame of the chassis. This is a "grounded circuit," As long as the outward conductors are in all cases insulated from the inward conductors—metal parts of the chassis—the effect is precisely the same as if the current went back through another wire.

The low-tension current from the battery to the timer can be returned to the battery through the same "ground" that carries the high-tension current back to the coil. The two currents do not interfere in the least. The reason is simple, if the idea of the necessity for a *complete and unbroken circuit* is kept in mind. There is no connection between the sources of the two currents—high and low-tension—and if the low-tension current found its way into the high-tension winding of the coil, to suppose an impossibility, it would find itself in a place that had no connection whatever with the battery. A current of electricity always takes the easiest and most direct path, avoiding "blind alleys" through which it could make no further progress. So the grounded currents return perforce each to their sources, and as long as the outgoing conductor is insulated, so that the current cannot pass from it to the ground—the metal of the car—before it has been led to its proper place and has done its work, there will be no trouble.

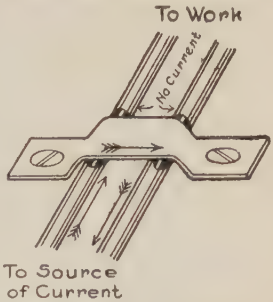


A GROUNDED SPARK PLUG

Electricity always seeks the easiest path, and the return through the broken insulation to the engine is easier than jumping the gap in the spark plug.

Remember, however, that electricity, as if it disliked work, always is on the lookout for short cuts which will take it back to its source before it has done anything. If, for instance, a wire leading the current out from the battery chafes against the frame until the insulation

is worn through and the bare wire touches the frame—ground—the current will immediately skip through the opening and go back to the battery through the frame, leaving out all the wires and everything else beyond the chafed place. This makes what is commonly referred to as a ground, or a short-circuit through ground.



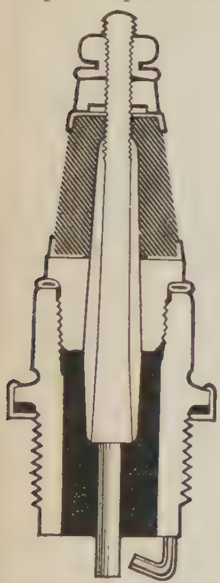
HOW GROUNDS OCCUR

The current will pass from one worn wire to the other through the metal clip, instead of travelling on through to the lights or the horn.

A plain "short-circuit" is where two conductors, one leading from and the other back to the source of current, come together in such a way as to make connection, as when two wires, both with the insulation gone, come together. The effect is precisely the same as that of a ground.

Principle of the Spark Plug.

No matter how a spark plug is constructed—and there are innumerable variations in details—it is always the same in principle and in its essential arrangement. There is an outer shell or body threaded to screw into the cylinder, and inside this a core of insulating material through the center of which runs a metal rod. The top of the rod, projecting above the insulating core, carries the terminal to which the high-tension cable is attached and the lower end, projecting into the combustion chamber, has a point or electrode of some heat-resisting metal—sometimes platinum, but more often a less expensive metal or alloy.



A TYPICAL SPARK-PLUG

A wire is attached at the top which connects with the center pin or the electrode. This is insulated from the outside, which is secured in the engine and forms the return of the current.

The gap between the sparking points varies to some extent according to the type of ignition system used. An ignition system in which a coil is used requires a somewhat wider gap than a high-tension magneto system. The maximum distance for a coil system is about 1-16 inch, and with a high-tension magneto the distance is from 1-64th to 1-32 inch.

The spark plug is an excellent example of the grounding principle. The shell is grounded to the engine—in contact with it—through its screwed-in part. The high-tension current is led to the plug through the high-tension wiring, and the central rod may be considered simply a continuation of this wiring and the core a continuation of the insulation on the wire. So the current is carried straight to the end of the central electrode, as it cannot pass through the insulating core any more than

it can through the insulation of the wire. It is true that there is a break in the insulation in the bare metal of the clip at the end of the wire and the terminal at the top of the central rod of the plug; but these are separated from all other parts by such a wide space of air that there is no danger of leakage. So the easiest way for the current to go is across the narrow gap between the central and the shell electrodes. As soon as the current has jumped the gap it starts its return trip to the coil or the magneto, as the case may be, traveling through the plug body to the engine, through the engine and whatever other parts may intervene to the point where the ground wire from the source of high-tension current is connected and thence to its source. That completes the circuit.

Causes of Spark Plug Trouble.

Anything that will prevent the current from making a clean jump from one electrode to the other will give rise to defective spark plug action.

In the first place, the current must be forced to follow the rod down to the point or electrode in the combustion chamber. It will do this if it cannot find its way through the insulating core and so get to ground prematurely through the plug body. But if there is a crack in the insulation the current will leak through, which is the reason a cracked porcelain core makes a plug useless. In the case of a plug with a mica core oil may work in between the layers of mica and provide a path which the current will readily follow across to the shell.

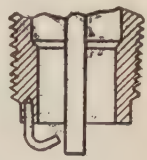
Bear in mind that a good ignition system will send a spark jumping across a gap of perhaps three-quarters of an inch in the open air. In the high compression of the charge at the time of ignition the jumping capacity is very much less; in other words, it is much harder for the current to pass a gap through compressed air than through air that is not compressed. That is one reason why the points are placed so close together. Because of the high resistance at the sparking points, the current will easily jump a much larger gap from the central electrode to the plug body through a crack in the insulation or across an oily path.

The high resistance at the points accounts for the fact that the current will follow a path of soot or carbon leading across a comparatively long stretch of the lower end of the core rather than leap the narrow gap. A very thin coating of carbon will not cause this kind of a short-circuit because the particles are not close enough together to form a sufficiently easy bridge. But a thick layer of carbon will do the trick. Oil on the plugs burns and leaves a deposit that will cause a "short,"

so that the engine with a tendency to work too much oil into the combustion chamber is likely to misfire unless the plugs are frequently removed and cleaned. Also, too rich a mixture will leave a sooty deposit with the same effect.

Adjustment of Points.

The distance between the electrodes or sparking points is important because if the gap is too small the spark will not generate enough heat in its passage to properly ignite the mixture. The effect may be to start combustion so feebly that maximum pressure of the burning charge will not be reached, or to fail to ignite altogether. If the mixture is not exactly right and the points are too close together there will probably be no ignition.



EXTENDED SPARK GAP

The space between the electrodes should be adjusted by bending the small wire set into the shell.

On the other hand, if the points are too far apart the current may not be able to jump across. In this case there is much greater liability to short-circuiting through a thin coating of carbon, or through a slight defect in the insulating core. If the current can just gather strength enough to make the jump it will generate so much heat that the points will be burned, which will widen the gap and soon stop the spark altogether.

Just here it may be well to revert to the function of the safety gap in the magneto, described earlier in this chapter. If the current cannot jump the plug points and cannot leak through the core or across a sooty path at the lower end of the plug, the safety gap will come into operation, indicating that the current cannot find a path back to its source in any other way.

"FLUSH" ELECTRODES

The only adjustment that can be obtained is by bending the central electrode slightly.

Sparking at the safety gap, therefore, means that there is a break in the circuit somewhere between the magneto and the grounded shell of the plug. So when the safety gap crackles, look first to see that there are no loose connections or breaks in the cables. If the wire comes off a spark plug, for instance, the safety gap will get into action. If all is right in the wiring the plug is at fault. See that the points are set properly and look for defective insulation if the plug still refuses to function.

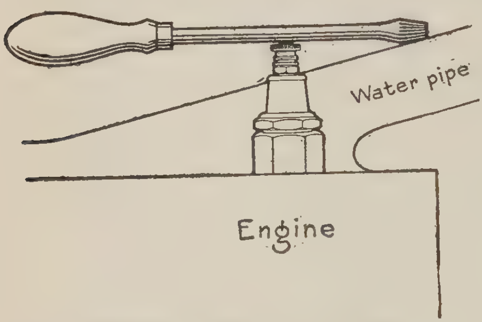
With these things in mind the reason for care in setting the points becomes clear. The time-honored gauge for the gap for coil ignition is a dime that has had its faces worn down to a blur, and for magneto ignition an ordinary visiting card.

Where a spark plug maker specifies a certain width of gap as being most advantageous, it is not difficult, as a rule, to get a slip of metal of the thickness given and use it as a gauge. Ordinarily the old dime or the card will answer very well.

In bending a point to alter the adjustment be careful not to mar the smooth surface of the wire and not to break it off. Do not try to bend the central rod unless it is the only electrode that can be bent, as is the case with some plugs having a rigid extension from the body for the shell electrode. Bending the rod may crack the porcelain.

Spark Plug Tests.

Before suspecting a spark plug make sure that the current is reaching it. While the engine is running take a screw-driver or any other tool with a wood handle—be careful about the handle, for if you touch the bare metal of the tool you will get a bad jolt—and touch the shank to the metal top of the central electrode, where the wire is clipped on, and bring the point close to the cylinder head or any other convenient part of the engine. If the current is getting as far as the plug it will jump from the point of the screw-driver to the engine, leaping a gap of from three-eighths to three-quarters of an inch. If you get no spark in this way you know the current does not reach the plug and it is in order to trace back and see if the wires are intact and properly connected.



TEST FOR IGNITION CURRENT

The screw-driver furnishes an easy path for the current. This serves to cut-out this particular cylinder, and if the engine runs appreciably slower, it is certain that the spark plug operated properly under normal conditions.

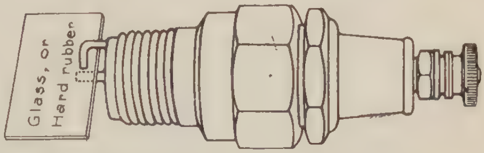
If you do get a spark, you will know that the trouble is in the plug. Take it out and examine it for defects. (See heading "Spark Plug Troubles" earlier in this chapter.) If you can find nothing wrong put in another plug. The original plug may have a hidden crack in the insulation, or the insulation may be porous, as is sometimes the case.

If there is missing in one cylinder, find out which cylinder it is. Short-circuit one plug at a time, as described, with a screw-driver. The cutting out in this way of the power of one cylinder that is working properly will make the engine run perceptibly slower. When you come to the missing cylinder, however, it will make no difference in the speed if the missing is regular, or only a little difference if the cylinder was firing only part of the time.

By listening to the engine it can readily be detected if more than

one cylinder is missing, for if one missing cylinder is short-circuited there will be breaks in the running of the rest that the ear will at once recognize.

Instead of using a screw-driver to find out if current is reaching a plug, the wire can be removed from the plug and the brass terminal held near the engine while running. If the current is coming there will be a spark. You ought to get a spark at least three-eighths of an inch long.



TESTING A PLUG FOR LEAKAGE

The current cannot penetrate glass or hard rubber. Small leaks in the insulation can be seen or heard if the progress of the current is thus interfered with.

There is one condition under which the screwdriver test will fail to tell the truth. If the sparking points have become jammed together, making a dead short circuit, the current will flow straight through them without causing any spark. Applying the screwdriver, however, will show no spark, and it will look as though no current were reaching the plug. For this reason, among others, an inspection of the plug is a wise move.

To test a plug for internal leakage through the insulation of the core, take it out, attach the wire, put a piece of glass, fibre or hard rubber between the points and with the engine running bring the body of the plug within about an eighth of an inch of the engine. If a spark jumps across to the engine it indicates a defective core because, with the path from point to point blocked, there is absolutely no way the current could get through without penetrating the core.

A Roadside Repair.

When a plug goes wrong on the road it is sometimes necessary to make a temporary repair, if possible, or at least such a repair may enable the engine to work properly until a new plug can be obtained. A broken porcelain, if the break is not too sharp an angle, will give temporary service if a thin rubber washer is inserted between the two broken parts and the nut tightened down. This, however, will not last long, for the heat will deteriorate the rubber. Sometimes a crack in the projecting upper part of the porcelain can be covered with a wrapping of tape so that it will prevent leakage for a while.

In many plugs the insulating core projects into a cup-like recess in the firing end. If such a plug refuses to spark and internal leakage is suspected, test it to see if the leakage is in the projecting part of the core by laying the plug on the engine, with the engine running and the wire attached, in such a position that you can look into the recess. This is best done in the dark, or by holding something over the plug to

exclude light as much as possible. If the leakage is in the projecting core the sparks can be seen.

Clean spark plugs with gasoline and an old stiff toothbrush. Most plugs are easily taken apart if a thorough cleaning is needed, but ordinarily this is not necessary. Watch, however, that carbon is not allowed to build up in the parts that cannot be reached.

Carbon.

Carbon on the plug body or the shell electrode will not have any effect so far as leakage is concerned. It should be removed, however, because if it gets thick it may cause preignition by becoming red-hot and carrying its heat over and igniting the next charge prematurely. This is especially likely to happen if the carbon is lumpy or builds up on projecting parts. As a matter of fact, this is true of carbon in any part of the combustion chamber.

If a plug is so badly carbonized that the deposit cannot be removed with gasoline and a toothbrush it can often be loosened by taking the plug apart and soaking the parts overnight in kerosene, finishing the job with the toothbrush and removing all traces of kerosene carefully. If this fails acetone will usually dissolve the carbon; but acetone is not always handy, and the usual recourse is scraping. This must be done with care to avoid destroying the glaze on the porcelain, if the core is of this material. Instead of scraping, a piece of fine sandpaper can be used to take off all but the last of the carbon. The final film will usually yield to vigorous rubbing with a rag and gasoline, or, if not, use a piece of fine sandpaper that is so nearly worn out that there is almost no scratch left in it. Always make sure that the points of the electrodes which are directly in the path of the current are perfectly clean and bright. They are cleaned in a second by passing a piece of sandpaper between them.

Always bear in mind that where sandpaper is used for cleaning spark plugs or contact points it must be fine sandpaper. No. 0 or No. 00 is good for the purpose.

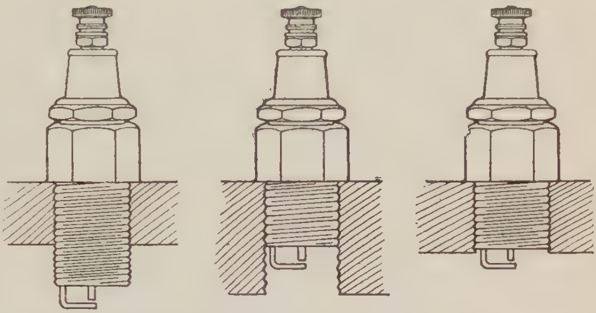
Using the Proper Plugs.

It makes a good deal of difference in the running of the engine and in the service given by plugs whether the right or the wrong plugs are used, and this is recognized by the makers of plugs, who usually specify which of their numerous models are best adapted to certain engines. There are so many really good plugs on the market, and so many models of each, that there is little or no difficulty in getting suitable plugs at any time and almost any place. The makers of engines also

are wide awake to this matter, and often specify the plugs that they have found to give the best results in their severe tests. You will not go astray if you stick to the recommendations of the engine maker or of a good plug maker.

How to Pick a Plug.

If you do not know just what plug to use or cannot get just what you know is right, get one that, when screwed in, will come about flush with the inside of the combustion chamber, or that projects inside the chamber slightly. If a plug is so placed that its points are back in a hole in the cylinder head it will always be pocketed with burned gas, and this may interfere with ignition. In some engines this point makes more difference than in others, but always it is better to avoid the pocketing.



SELECT THE RIGHT TYPE OF PLUG

The one at the left projects too far into the cylinder and the piston or valves may bend the electrodes; the one in the center is too short and will fire only in a pocket of bad gas which reduces the efficiency of the combustion; the one at the right is of the proper length and type for the engine as shown.

On the other hand, take particular care that the plug does not project too far into the combustion chamber. The cooler the plug can be kept the better, and the further it projects the harder it will be to cool and the hotter it will get in service, even to the point of causing pre-ignition and burning away the electrodes. Further, in some engines there is so little clearance above the piston, or above the valves, according to the location of the plug, that one or the other may strike the plug and put it out of business immediately. A plug that projects much is more liable to trouble from oil than one that is flush.

Plugs Must Be Compression-tight.

It is important that there should be no leakage of compression around the threads of the plug body. The fact that a plug may screw in hard does not by any means ensure that it will not leak. As a matter of fact, in most cases the threads alone cannot be depended upon to prevent leakage. The plug should screw right down to the shoulder, and come down tightly on the little copper gasket. There is an exception to this in plugs with tapered thread screwing into a tapered hole. The taper usually will make the plug sufficiently tight.

It is a good idea to put a little oil mixed with graphite on the threads of a plug before screwing it in, being careful, however, not to get the mixture on the insulation and to keep it out of the cylinder, for graphite is a good conductor of electricity and its sloppy use may cause short-circuiting. The lubrication will prevent the plug from sticking if it is not removed for a long time.

It is not necessary to screw in a plug very hard, if it is properly fitted. In fact, if it is screwed in too hard while the engine is cold the expansion of the metal of the engine and of the plug itself when the engine heats up may make it very difficult to remove the plug without allowing the engine to cool. This is because the plug itself expands with the heat while the expansion of the iron of the cylinder contracts the hole and clamps the threads hard and fast.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER VI

Why little things are important in ignition.

Why adjustment should always be made in the right direction.

Why a knowledge of principles is more important than a knowledge of details

What determines the strength of ignition currents.

Why high-tension insulation needs special care.

How high-tension current is produced.

How a coil works.

How a timer works.

How a distributor works.

Why the spark must be advanced and retarded.

How to determine the proper ignition time.

Why retarded ignition causes heating.

How ignition time affects power.

How to handle the ignition in driving.

How to illustrate the working of the timer and its effect on the running of the engine.

How the timer is constructed.

How to keep the timer in good condition.

What the high-tension magneto is and how it works.

What the interrupter is, and how it works.

How to keep the interrupter in good condition.

How to set the interrupter points.

How to keep the points in good order.

How to restore burned or pitted points to good condition.

How to keep the interrupter in place.

How brushes are made and used.

How to take care of brushes.

How to locate and cure magneto trouble.

What to do if ignition fails suddenly.

What to do if ignition fails gradually.

What the safety gap is, and what it indicates.

What a low-tension magneto is.

How to care for a low-tension magneto.

How to take care of a coil.

What care is required in making connections.

What a vibrator coil is.

What the vibrator is for.

How the vibrator works.

How to adjust and care for the vibrator.

How to adjust for spark efficiency.

How to adjust for current economy.

How to cure misfiring in a vibrator coil ignition system.

How to dress very hard contact points.

What the condenser is and what it does.

How to recognize condenser trouble.

What a grounded circuit is.

What the habits of an electric current are.

What a short-circuit is.

What the principles of the spark plug are.

How the spark plug is grounded.

Why spark plugs give trouble.

How to test for spark plug troubles.

How to adjust spark plug points.

How to detect which cylinder is missing fire.

How to test a plug for internal short-circuiting.

How to temporarily repair broken plugs.

How to clean spark plugs.

How to pick out the right plug for your engine.

How plugs are made compression-tight.

How to keep plugs from sticking.

CHAPTER VII

CARBURETORS

What the Carburetor Does.

The carburetor takes in gasoline and air, sprays the gasoline into the finest possible particles, mixes it thoroughly with the air and so forms a mixture which, normally, is of such proportion that it ignites readily and burns cleanly, leaving no residue.

The carburetor must, of course, handle larger or smaller quantities of air and gasoline, according to the varying speed of the engine. It is therefore provided with means of adjustment. There are two kinds of adjustment, one set by hand and the other automatic, taking care of itself while the engine runs. The hand adjustment is to set the carburetor right in the first place, so that there will be a proper proportion between the flow of gasoline and air. The automatic adjustment maintains this proportion throughout changing engine needs and is designed to give the engine as nearly as possible the best mixture regardless of speed changes.

For its operation the carburetor depends solely upon the suction of the engine. When the piston of a cylinder goes down on the intake stroke it "draws" through the carburetor for the simple reason that there is no other inlet open to the cylinder. The faster the piston moves the more air it must draw in in a given time and the greater the suction effort.

This matter of suction, to use the popular term, is at the bottom of carburetor action. It is readily illustrated.

Carburetor Action.

Take a glass full of water, hold your lips to it partly closed, and draw in air. You will have to pull hard, and the air rushing in will draw some of the water with it. Open your lips a little wider and you will get more air and less water. Open them wide and you will get nothing but air. Your lips correspond with the air passage of the carburetor and the glass of water with the gasoline spray nozzle or jet. When the engine sucks in air, precisely as you do, the air is carried past a little open-ended pipe in which gasoline stands almost level with the opening. The current of air draws the gasoline from the nozzle precisely as you drew water from the glass, and sprays it in the same

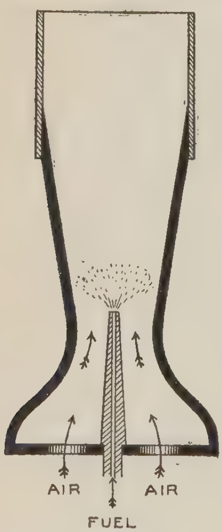
way, only it is broken up into a much finer spray. If the air opening in the carburetor is made small, as when you almost closed your lips, the gasoline is drawn out rapidly with the swiftly-moving air current. If the air opening is made larger a smaller quantity of gasoline is taken up. Obviously, if the carburetor air opening is too large, then, there will be too much air and not enough gasoline, while if it is too small there will be too much gasoline in proportion to the volume of air.

Hand Adjustment.

The hand adjustment of the carburetor may act on the air or on the gasoline or on both. That is, there may be a valve to regulate the flow of air, or a valve to regulate the flow of gasoline, or both. As a matter of fact, there is practically in all carburetors a "needle-valve" to regulate the flow of gasoline. Some carburetors have no air adjustment and some have both kinds.

The Venturi Tube.

A very large proportion of the almost innumerable forms of carburetors use what is called a Venturi tube for the air passage. This is a tube that is constricted, or made smaller in diameter, near the point where the gasoline is drawn out of the spray jet. Its advantage is that it gives a sufficiently rapid flow of air to draw out enough gasoline without making the passage too small—which would tend to "choke" the engine and make it work harder to get sufficient air and, consequently, reduce the power. The spray jet projects into the center of the tube, and its position with reference to the constricted part is of the highest importance. Another advantage of the Venturi—which is named for its originator—is that it gives more nearly the same mixture at varying engine speeds than a plain tube, or one of the same diameter throughout its entire length.



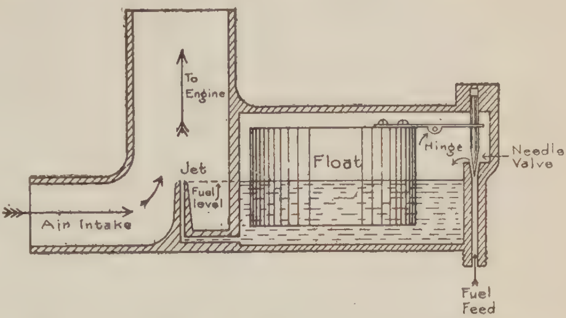
THE VENTURI

The decrease in size of the tube increases the speed of the air at the point where it passes the gasoline nozzle, thus increasing the suction.

Float Feed Principle.

If gasoline were piped direct to the spray nozzle from the tank there would be a continuous flow from the nozzle and control would be impossible. Moreover, it is necessary that the gasoline should stand at a constant level in the nozzle—a small fraction of an inch below the opening. The float-feed system provides for this.

The gasoline from the feed-pipe leading from the tank runs into a chamber called the float chamber through a small valve. In the chamber is a float of cork or hollow metal. The float is connected with the little valve in such a way that when the float is resting on the bottom of the float chamber—as it would if emptied of gasoline—the valve is held wide open. Turn on the gasoline, and it flows freely through the open valve into the float chamber. As it flows in, it raises the float, and as the float rises it gradually closes the valve. When the gasoline reaches a predetermined level the valve closes tight, stopping the flow. If a little gasoline is taken from the float chamber the float falls a little, opens the valve a little and again gasoline flows until the level is reached, when the valve again closes.



ELEMENTARY CARBURETOR

The flow, through the action of the float, keeps the gasoline level at the top of the jet. Air passing by the nozzle on its way to the valve, due to the partial vacuum caused by the suction in the engine, takes with it a fine spray of gasoline.

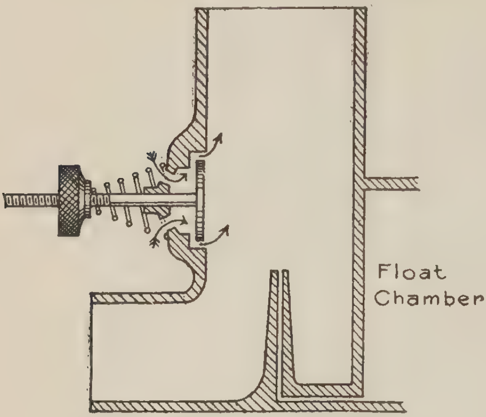
A second gasoline passage connects the float chamber with the jet. It is one of the familiar laws of physics that any liquid in separate chambers will rise to precisely the same level in both if there is a connecting passage through which the liquid can flow. Therefore the gasoline in the jet rises to exactly the same height as the gasoline in the float chamber. When gasoline is drawn from the jet, as is the case when the engine runs, it lowers the level of the gasoline there and the float promptly opens the valve and lets in enough to restore the level. Thus the constant level is maintained.

In actual operation the gasoline flows constantly out of the jet and constantly through the float-valve, the float being so adjusted as to permit this. As soon as the engine stops and the flow from the jet ceases the float closes the valve and prevents the gasoline from running through to waste.

If anything happens to prevent the float-valve from closing at the proper time, gasoline continues to flow and drips out of the carburetor. That is "flooding." The same thing happens if the float is so set that it does not close the valve before the gasoline reaches the top of the jet. The level in the float chamber will be higher than the top of the jet and the gasoline, trying to reach the same level as in the chamber, continuously flows out.

Auxiliary Air Valves.

If the carburetor is so adjusted that the current of air will draw just enough gasoline to run the engine properly at low speed, the increased suction at higher speed will draw from the jet an excess of gasoline, forming too rich a mixture. This trouble is overcome, in many carburetors, by the use of an auxiliary or extra air valve which opens more and more as the speed and suction increase. The larger air passage reduces the suction on the jet and also the quantity of gasoline drawn from it.

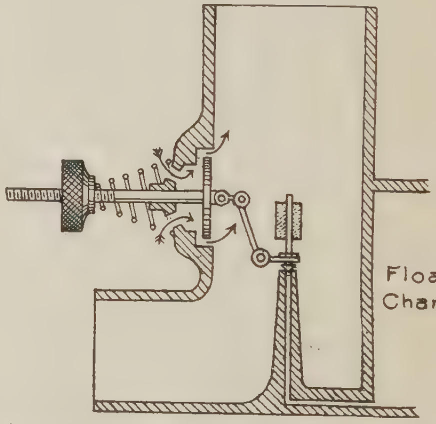


THE AUXILIARY AIR VALVE

At increased suction, gasoline flows at a higher rate of increase than the air; consequently, at high speeds the mixture would be too rich were it not for some means of reducing the gasoline flow or increasing the air flow.

Go back to the experiment with the glass of water. While drawing air and water through your partly closed lips let air enter through your nose. At once the amount of water drawn in decreases. Your nose is an auxiliary air valve. It works on precisely the same principle as the conventional extra air valve in a carburetor.

But the auxiliary air valve is automatic in operation. It is normally held closed by a spring and remains closed while the engine runs at slow speed. At higher speed, however, the suction opens it against its spring, and the higher the speed and the greater the suction, the wider it opens. Usually an adjustment is provided, acting on the spring. The more the spring is compressed the higher must be the engine speed before the valve can open and the less it will open when it starts and the less extra air will be drawn in and this, in turn, means more gasoline. The whole effect of the extra air valve is to check the tendency of the nozzle to increase the richness of the mixture as the speed increases.



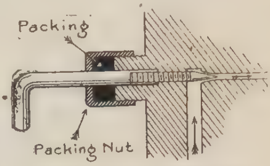
AUXILIARY AIR VALVE CONNECTING WITH THE JET

The levers actuate a small needle so that the gasoline flow is proportionate to the increased air flow.

In some carburetors a series of auxiliary air openings is used, each

closed by a steel or bronze ball. The balls are raised from their seats as the suction increases and allow extra air to pass. The principle is precisely the same as that of the spring-loaded valve, however, for the weight of the balls simply takes the place of the pressure of the spring and the action is the same.

Like everything else about a carburetor, various makers have various ways of designing their air valves. But the principle understood, the operation of any valve is readily grasped. The same is true of the float-valve mechanism.



A TYPICAL NEEDLE VALVE

This forms a tight seat, is easily ground and offers various adjustments.

What a Needle-valve Is.

A valve to regulate the rate at which gasoline flows from the float chamber to the jet is placed at some point in the passage between the two, and this is always called a needle-valve. This is simply a screw with a long, tapering point which can be screwed into a seat of the same shape. This type of valve is used because it allows more delicate and close adjustment than any other practical form, and it is exceedingly simple and not likely to give trouble.

Automatic Regulation of Both Gasoline and Air.

Both air and gasoline are antomatically controlled in many carburetors by connecting the auxiliary air valve with a needle-valve. In such a carburetor the gasoline and air openings are so proportioned that there will be a proper mixture at low speed or idling, when the automatic device is inoperative. At the higher speeds the air opening increases faster than the gasoline opening, and so maintains as nearly as possible a constantly correct proportion.

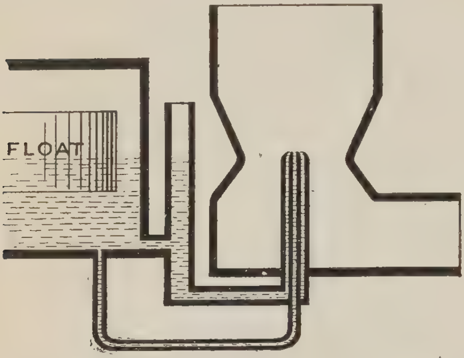
The greatest difficulty in designing carburetors and making them operate properly is due to the fact that if means are not taken to avoid it the percentage of gasoline to air will constantly increase as the speed and suction increase. This is precisely opposite to what is needed, for a fast-running engine requires a mixture a little leaner, if anything, than at slow speed.

Automatic extra air valves and automatic gasoline-regulating valves are designed to overcome this difficulty. In many cases excellent results are obtained.

Two-jet Principle.

The problem has been attacked in an entirely different way in the case of another carburetor. The outstanding feature of this is that

it has a compound jet, or two jets combined in one. One of the jets is of the ordinary type, in which the flow of gasoline increases with an increase of speed and tends to enrich the mixture excessively. The other jet, however, is of a special type, and it works in precisely the opposite way. That is, it delivers the same quantity of gasoline at all times, regardless of speed, so that the faster the engine runs the poorer the mixture would be if this nozzle were the only one. By using these two opposites a constant mixture is obtained, one nozzle supplying extra gasoline as the flow from the other falls off, and vice versa. Needless to say the proportions are carefully worked out.



THE COMPOUND NOZZLE

The inside jet gives out too rich a mixture at high engine speeds. The outside jet, which is connected with the air, gives too lean a mixture at high engine speeds. The combination of the two gives a correct mixture at all speeds.

The principle of the constant-flow nozzle, which tends to give a poorer mixture as the speed increases, is simple. The gasoline passage leading to this nozzle communicates with a little vertical well which is open to the air at the top and is carried high enough so that the gasoline will not overflow; all that is needed is to carry the well higher than the gasoline in the float chamber. It is this well that prevents the increase of quantity of flow as the speed increases. There are no air adjustments. Adjustment is made on the gasoline for low speed, and at all other speeds the compound nozzle takes care of the mixture.

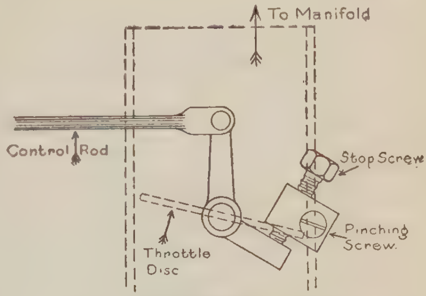
Duplex Carburetors.

Engines with eight and twelve cylinders complicate the carburetor problem because of the cross currents caused by feeding to two blocks of cylinders at the same time. Two carburetors, one for each cylinder block, give difficulty because it is next to impossible to obtain equal and at the same time efficient adjustment in both. The duplex type was evolved, consisting of two sets of nozzles and mixing chambers combined in one instrument and fed by a common float-feed chamber. By using the same air inlet for both and mounting two throttles on a single shaft, uniform action is obtained.

Throttle Valves.

The throttle valve controls the flow of the mixture to the engine, after it has been formed in the carburetor. It is a simple valve of the

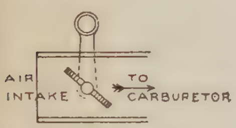
"butterfly" type—a disc pivoted in the middle. The mixing chamber is the space above the jet and Venturi where the gasoline and air mingle. Usually an adjustable stop limits the closing of the throttle so that it stops just at the point where the valve remains open enough to allow the engine to run at the lowest practicable speed. This is the idling speed. When the throttle is wide open it stands parallel with the flow of mixture, offering a minimum of resistance.



A THROTTLE VALVE
Adjusting screws are used to prevent this from closing entirely so that sufficient mixture can be obtained at all times to keep the engine from stalling.

Chokes.

Starting a cold engine, especially in cold weather, generally calls for a somewhat richer mixture than starting a warm engine, or running once the engine has been started. This is largely because a good deal of the gasoline is condensed on the cold walls of the passages and the cylinders and cannot be ignited, so that to get enough fuel into the air an excess must be supplied. A butterfly valve in the main air opening, which can be partly closed when starting, restricts the flow of air and increases the flow of gasoline. The same result is obtained by the carburetor primer, or "tickler," which commonly is a little button which, when pressed down, pushes the float into the gasoline in the float chamber, raising the level above the normal point and causing gasoline to run out of the nozzle.



THE CHOKE
Reducing the air to the carburetor increases the proportion of fuel that reaches the mixture and makes starting easier.

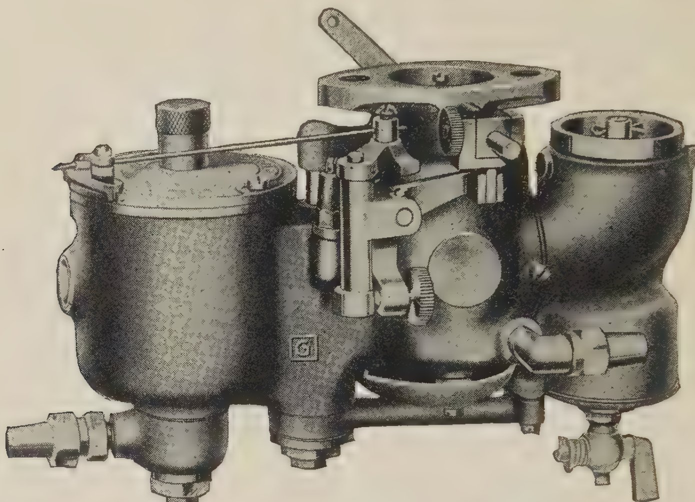
The choke or an adjustment on the gasoline feed is often connected with an adjustment on the dash so that the carburetor can be to some extent regulated while running.

Multiple Jets.

Instead of using one or two comparatively large jets some carburetors use a series of very small jets which are opened one at a time by connection with the throttle or automatically by the air valve as speed increases and more gasoline is required. The openings are so small that a number of them must be opened to give sufficient fuel for anything but idling speed, and controlling the number of openings accurately controls the supply.

Carburetor Adjustment.

The adjustment of the average carburetor is by no means difficult if it is undertaken with an understanding of what is required, and if, when making adjustments, it is known what should be expected. For instance, it would be foolish to turn an adjusting screw without knowing



A MODERN TYPE OF CARBURETOR

The throttle in connection with the intake manifold is shown at the top center, the auxiliary air valve is shown at the right. The float chamber is the cylindrical portion at the left. The pipe at the left receives the gasoline supply; that at the right is connected with the cooling system to furnish heated water to the jacket to assist in vaporization.

why it was being turned or the effect produced by turning it in a given direction. As a general guide, remember that a needle-valve screwed in—that is, turned in the direction of movement of the hands of a clock—decreases the flow of gasoline, while an auxiliary air adjusting screw turned in the same direction tightens the spring, decreases the supply of air and makes a richer mixture.

Generally the needle-valve is used only to give a proper mixture at idling speed. Adjustment for higher speeds is effected through the auxiliary air.

Start out with the air valve resting lightly on its seat. Be careful about this, for if the valve is not closed to begin with there will be difficulty from the start. Only a very light spring pressure is required.

Close the needle valve by screwing it in as far as it will go. Do not force it when it stops, or the valve and its seat may be cut. Closing the valve gives a definite starting point. Set the throttle in idling position. Then open the valve, say half a turn—it will vary a good deal in different carburetors. Start the engine, priming if necessary.

If the engine will not start, or fires only a few primed charges, open the valve a little more and try again. When the engine is running see that the auxiliary air valve does not lift, if it is possible to observe this point.

There are two ways of knowing when the proper idling adjustment is obtained. One is to simply adjust the needle-valve until the engine runs its best with the idling throttle position. The other is to open the pet-cocks and note the flame that shoots out. When the mixture is right the flame will be a light blue and almost invisible. Too rich a mixture will cause a red, smoky flame and too lean a mixture a yellowish flame.

Now you have the low speed adjustment.

Open the throttle until the engine runs at about its normal road speed and adjust the auxiliary air valve, judging the mixture as before. Leave the needle-valve alone; the auxiliary air will do it.

Back-firing through the carburetor indicates too weak a mixture. Screw down the auxiliary air to make it richer.

In many carburetors there are no further means of adjustment. If, having reached this point with such a carburetor, it is found that the engine backfires at high speed, indicating too weak a mixture, the auxiliary air valve can be tightened down further or the needle-valve opened until the back-firing ceases. This will mean, however, that the mixture will be too rich at low and intermediate speeds. In such a case it is usually best to adjust for the intermediate, or regular running speed, this giving the best average results.

In other carburetors there is a separate adjustment for high speed, and this is set, not by racing the engine continuously, but by opening the throttle just for a second and then bringing it back to intermediate position. The same principles apply as in setting for intermediate speed.

In all cases consult the instruction book to find out how the carburetor is made and how it works and what the adjustments are. Otherwise you will be working in the dark.

In making carbureter adjustment see that the spark is advanced, at each stage, as far as it should go. After opening the throttle to the desired point advance the spark until the engine ceases to pick up speed. Further advance will cause knocking.

Adjusting Old Carburetors.

A carburetor that has seen much service will sometimes present rather puzzling problems in adjustment.

It may be that the engine will insist upon running, and even running

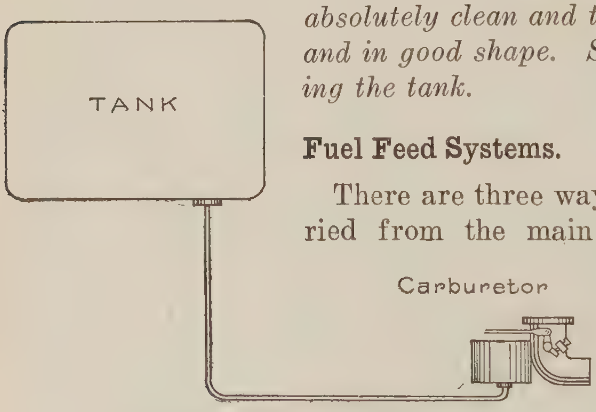
with too rich a mixture, when the needle-valve is closed as far as it will go. This indicates that the valve leaks and needs grinding. Grind it in with a mixture of powdered pumice and oil, using only a very small quantity and pressing very lightly. The principle is the same as that which governs valve grinding. If the valve cannot be made tight in this way take it to a repairman.

If the carburetor floods, gasoline dripping from it when the engine is not running, see first that the float is set at the proper height. Uncover the spray nozzle and it will be found that gasoline can be seen flowing from it. To check this the float must be lowered so as to close the float valve earlier. In some carburetors there is an adjustment for this purpose, and in others it is necessary to slightly bend the arm connecting the float with the valve. Do this very carefully and only a very little at a time until the gasoline just ceases to flow from the nozzle. It should stand level with the tip, or just a shade below.

If it is impossible to stop flooding in this way the float valve leaks. Test this by gently raising the float until the valve is positively closed. If the flow continues, grind the valve in the same way the needle-valve was ground, with powdered pumice. If the valve is in very bad shape the repairman will have to reseat it or put in a new one, according to the construction.

A new valve and an old seat will not fit, in ninety-nine cases out of a hundred, so either both must be new or they must be fitted—a repairman's job.

Dirt in a carburetor will spoil all your calculations. Be certain it is absolutely clean and that the strainers are clean and in good shape. Strain your gasoline in filling the tank.



THE SIMPLEST TYPE OF FUEL FEED

This is known as the gravity system. The tank is placed above the carburetor so that the fuel flows to the latter without the necessity of pressure or suction.

Fuel Feed Systems.

There are three ways in which gasoline is carried from the main tank to the carbureter; gravity, vacuum and pressure.

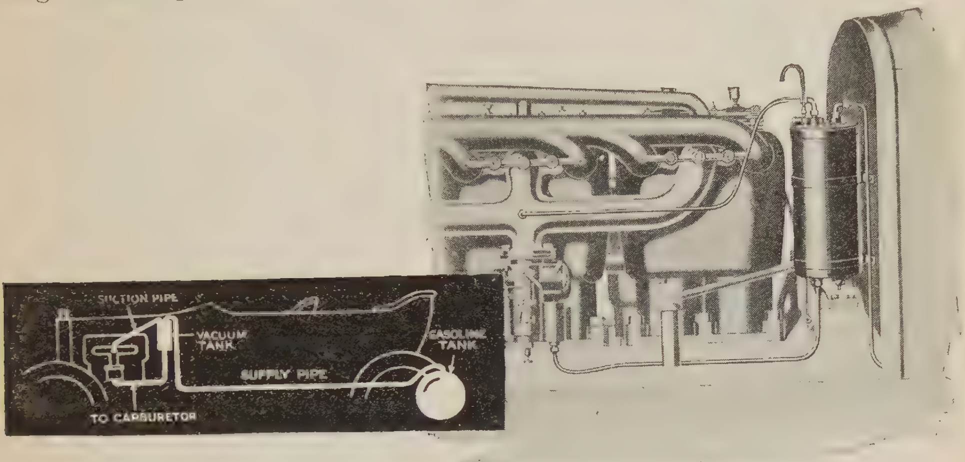
In the gravity system, which is the simplest, the tank is placed high enough so that the fuel will always flow freely to the carburetor.

In the vacuum system the tank may be placed anywhere, no matter how low. Fuel is pumped from it by a device operated by the suction

of the engine and delivered into a little auxiliary tank forming part of the device, whence it flows by gravity to the carbureter.

The vacuum tank is simply a pump which draws gasoline from the main tank and delivers it to a little tank below the pump, in the same casing. The flow to the carburetor is by simple gravity.

Briefly, the pump is actuated by the suction of the engine. The apparatus is connected with the engine in such a way—through piping and check valves—that a partial vacuum is formed in a chamber. Then a valve automatically opens and shuts off the suction connection with the engine and opens a valve in the line from the main gasoline tank. The



THE VACUUM FEED SYSTEM

The suction is produced by the engine and the small tank stores a sufficient amount of fuel to feed the carburetor under all conditions. The system is entirely automatic in its operation and will feed fuel to the carburetor even when the main tank is nearly empty and the car is climbing a steep hill.

partial vacuum in the chamber draws gasoline from the tank, delivers it to the little auxiliary tank and the whole cycle starts over again automatically. The faster the engine runs the faster the pump works.

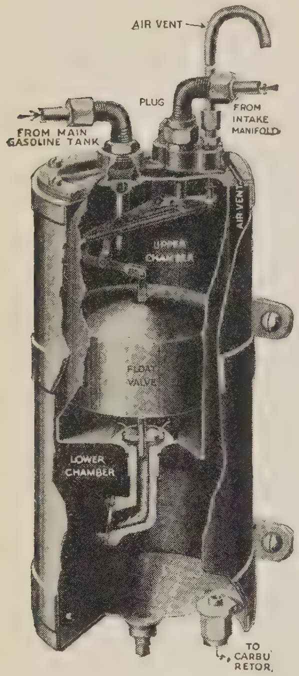
In case the vacuum tank is empty when it is desired to start the engine all that is necessary is to turn the engine over a few times with the throttle closed. This will replenish the auxiliary tank and feed the carburetor.

Other feed devices are made which use the pressure of exhaust gas to operate a diaphragm pump, transferring fuel from the main tank to the auxiliary.

In the pressure system also the tank may be placed anywhere. Air is pumped into the tank and the pressure forces it to an auxiliary tank connected directly with the carburetor. In some cases the pressure is obtained by allowing a little gas from the engine to go to the tank, the gas being cooled and strained on its way. Both hand-pumps and engine-

driven pumps are used to supply air pressure. A hand pump is always necessary, however, to supply the initial pressure to start the engine.

Whatever the system is, the main thing is to keep it clean and all passages unobstructed. A trap to catch sediment and water is placed in the fuel line, sometimes being part of the carburetor itself. This has a chamber at the bottom through which foreign matter can be drained out, and this should be opened frequently for a second or two.



THE VACUUM TANK

A float actuates the valves which control the connection with the outside air and with the suction of the engine. The lower section of the tank is kept filled and feeds directly to the valve chamber of the carburetor.

In the case of a plain gravity system there is always a small hole—sometimes more than one—in the filler cap. This is to admit air to replace the gasoline as it is used, and it must always be kept open and clear. If the hole becomes stopped the engine will exhibit all the symptoms of a partly-closed needle valve and will slow up and finally stop. Bear this in mind in case of unaccountable missing and irregular running.

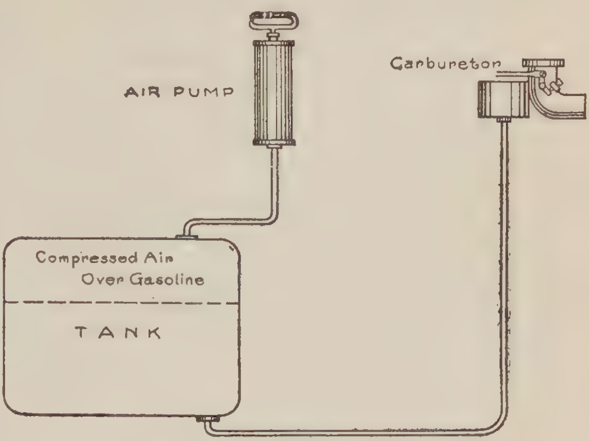
Sometimes the feed pipe leading from the gasoline tank to the carburetor is bent into a loop, the idea being to give the tube elasticity and prevent breakage from vibration. If this loop is in such a position that the gasoline has to flow up and then down, it is possible that air may be trapped in the upper part of the loop, forming an "air-lock" which will stop the flow. This is more likely to occur when the tank is not very high above the carburetor. The remedy is to turn the loop to a horizontal position, so that the fuel will always flow downward.

Gasoline will find its way through leaks too small for water to get through, and connections must therefore be carefully made. In putting together pipe connections the main thing is to see that before screwing them up they are perfectly in line, so that they do not have to be forced into position for coupling up. They should make tight joints without excessive tightening. A leak in a coupling properly put together and moderately tight is rarely cured by applying brute force to the wrench.

Do not use rubber where gasoline touches it, except for a very temporary makeshift repair or something of the sort. Rubber dissolves in gasoline readily.

In a pressure system the check-valves must be kept clean, and this is all the attention they are ever likely to need—if they need even that. Their work is very light and wear is very slow.

The "vacuum tanks" now so widely used are reliable affairs and seldom give trouble. Cleanliness is the main thing, as in the rest of the gasoline system, and means are provided for cleaning strainers.



THE PRESSURE FEED SYSTEM

The air is compressed by a hand-pump for starting, and thereafter by the action of the engine. The filler cap on such a system must be kept perfectly tight to prevent the escape of pressure.

A vacuum tank should not be blamed for carburetor trouble. As long as the carburetor is kept supplied the vacuum tank is doing its duty, and further than this it has no effect on the carburetor. The tank should not be placed where it will get too hot as this may interfere with its operation, and it should be at least three or four inches above the carburetor.

The air-hole in the main tank is very important where a vacuum tank is used, and its stoppage will prevent the working of the system.

When trouble occurs with a vacuum tank it is more likely to be from dirt than anything else, for the parts are simple and rugged and not liable to derangement.

They can be quite easily disturbed, however, by unskilled hands, and therefore the tank should be left alone, apart from following the simple directions given for its care in the instruction book.

Cleaning Fuel Pipes.

Clogged fuel pipes may be cleaned by pushing a wire through and then pulling through a bit of rag. After that, rinse out with gasoline.

As a matter of fact, this should never be necessary and will not be if the gasoline is strained and proper attention is given to the trap.

Water in Gasoline.

Water may find its way into the system even if it does not go in with the gasoline. Moisture in the air condenses on the inside of the tank

and the water at once sinks to the lowest level. The trap is always placed low down to take advantage of the weight of such water. This occurs more in winter than in summer, and if the water is not drained off it may freeze in the line and stop the flow of fuel.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER VII

What the carburetor does.

How the carburetor does it.

How to illustrate carburetor action.

How carburetor adjustments act.

What a Venturi tube is.

How the float feed works.

What may happen in the float feed.

How to cure float feed troubles.

What auxiliary air valves are.

How to adjust auxiliary air valves.

What a needle-valve is.

How to adjust a needle valve.

How to grind needle-valves and float-valves.

How both air and gasoline are automatically regulated.

What a two-jet carburetor is.

How the compound jet works.

What a duplex carburetor is.

What the throttle is.

What the choke is.

How the multiple jet carburetor works.

How to adjust a carburetor from the beginning.

How to adjust an old carburetor.

What causes flooding, and how to stop it.

How to adjust the float.

How fuel is fed to the carburetor.

What gravity, vacuum and pressure feeds are.

Why the air hole is important.

How to clean fuel pipes.

How water affects the system.

CHAPTER VIII

COOLING

Why Cooling is Necessary.

The engine derives its power from pressure caused by heat, the heat being obtained by burning gasoline in the cylinders. Heating a gas always causes it to expand, and it is this expansion that drives the piston.

Therefore heat is the source of this power—of all power in fact.

But the burning gasoline produces more heat than the engine can convert into power, and this extra heat simply goes to heat up the parts. This cannot be allowed, as the heat would first destroy the lubricating oil and would then make the valves red hot, and expand the pistons and rings until they stuck fast in the cylinders.

Cooling systems are used to carry away this excess heat and dissipate it, through the radiator in the case of the water-cooled engine. In an air-cooled engine the heat is transferred directly from radiating ribs or flanges on the cylinders to a current of air.

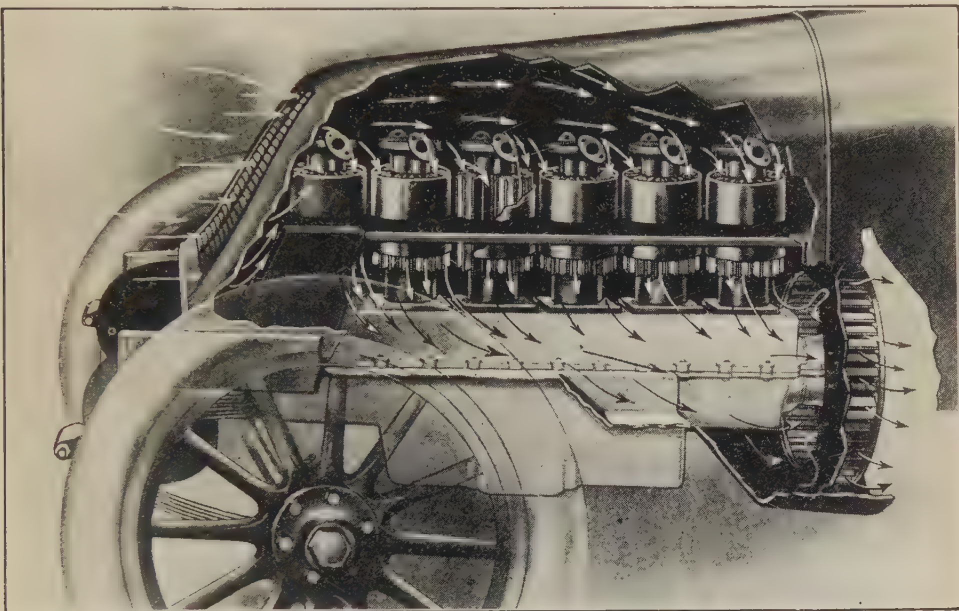
How Engines are Air-cooled.

There is little or no difficulty in air-cooling a small engine even without the aid of a fan and despite the fact that air is not as good a conductor of heat as water. The area of the cylinder walls in proportion to the cubic capacity of the cylinders is sufficient to provide a comparatively easy escape for the heat. The flanges on the outside expose a large surface to the air and are rapidly cooled, and as heat always flows from the hotter to the cooler part, there is a constant flow from the inside to the outside. The greater the difference between the temperature of the inside of the cylinder and that of the outside the faster the flow of heat will be.

As the cylinder diameter increases, however, the proportion between capacity and cylinder wall area increases the wrong way—that is, the capacity increases faster than the wall area. So the bigger the cylinder the harder it is to air-cool it. Therefore there are plenty of small air-cooled engines—on motorcycles—but very few large ones. In fact, there is but one conspicuously successful air-cooled car today.

In the engine of this car the cylinders have vertical flanges and are

surrounded by sheet metal jackets. In fact, the whole engine is enclosed in sheet metal, excepting the cylinder heads. Through the jackets air is drawn at high speed by fan-blades formed on the flywheel. The sheet metal casing fits as closely as possible around the flywheel, so that it is quite efficient in moving the air. The result is very efficient and satisfactory cooling and, as the fan is an integral part of the flywheel, there are no extra moving parts.



A SUCCESSFUL AUTOMOBILE ENGINE COOLING SYSTEM

The arrows show the direction of the air. The suction fan is embodied in the fly-wheel. The engine and individual cylinders are encased so that all of the air must pass down close to the radiating surface.

How Engines are Water-cooled.

In a water-cooled engine the cylinders are surrounded by an outer casing which usually is an integral part of the cylinder—cast in one piece with it or with the block of cylinders—but occasionally is a separately applied jacket of sheet metal. The space between the cylinder and the casing is filled with water. Where a detachable cylinder head is used the head also has a water space, and openings in the under side of the head register with openings in the top of the cylinder block, so that water flows freely from one to the other.

Use of the Radiator.

The water in the jackets, however, would boil away in a very short time if not constantly changed, as is often the case in stationary en-

gines, or taken away and cooled and then returned to the cylinders, as in the automobile engine.

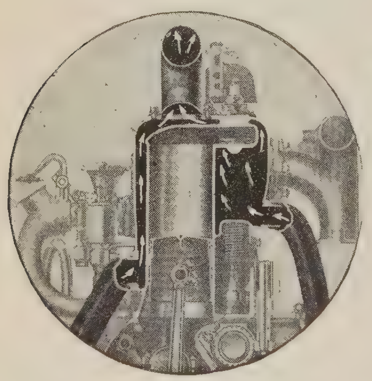
As it is impracticable to carry a large enough quantity of water to give time for slow cooling, means are provided for cooling the water very rapidly, so that a small quantity is used over and over again. The radiator does the work of cooling.

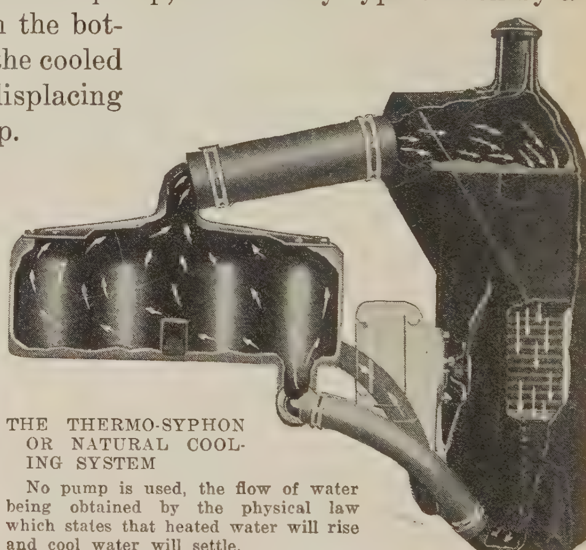
The heated water is carried away from the engine through a pipe in the cylinder head and goes into the top of the radiator. It cools rapidly as it passes from the top to the bottom of the radiator and is returned to the lower part of the water jacketing, through another pipe, from the bottom of the radiator.

How the Cooling Water is Circulated.

It is of great importance that the water should circulate rapidly, for if allowed to remain too long in contact with the cylinders overheating would follow. The radiator must be able to cool the water sufficiently in the brief time the water requires to pass through.

Two circulating methods are in common use—pump and thermo-syphon. In the pump system the pump, of a rotary type driven by an auxiliary shaft, is placed in the bottom water passage, forcing the cooled water into the jackets and displacing the heated water at the top.





THE THERMO-SYPHON OR NATURAL COOLING SYSTEM

No pump is used, the flow of water being obtained by the physical law which states that heated water will rise and cool water will settle.

In the thermo-syphon system there is no pump. The pipes are plain and clear and are made as large as possible, and everything is done to permit the water to flow very freely.

The system is based on the fact that hot water is lighter than cold water and has an active tendency to rise, much as oil will rise in water. So when the water in the jackets of a thermo-syphon cooled engine gets hot it rises to the top and pushes over through the upper pipe into

the radiator. Here it is cooled and, following the natural law, goes to the bottom of the radiator and thence back to the jackets.

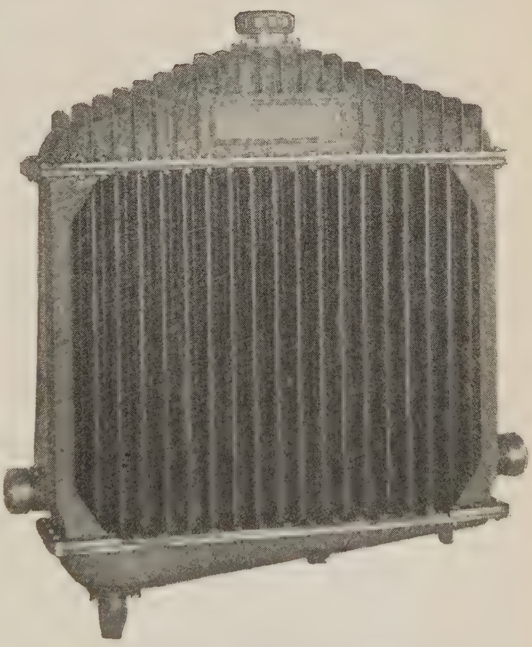
The Radiator Principle.

It has been a long and difficult task to bring the radiator to its present excellence, for it has presented many problems. The chief trouble was found in making the water-containing parts strong enough to stand the vibration of service while having walls so thin as to offer the least possible resistance to the passage of heat from the water to the air.

Put hot water into a cup and it will stay hot for some time. Put the same quantity of hot water into a wide, shallow plate and it will cool very rapidly. This is the principle of the radiator—to spread the cooling. In the radiator, of course, the water cannot be exposed directly to the air; but it is spread out in very thin passages of thin sheet metal which is exposed to the air.

The Tubular Radiator.

A simple form of radiator is made with a small tank, or "header" at the top, into which the hot water from the engine flows, another little tank at the bottom, from which the water flows back to the engine, and a series of vertical tubes connecting the two tanks. In many radiators for heavy service, such as motor truck and tractor service, the tubes are round. But though a round tube is strong, it offers a smaller cooling surface than any other form, and a large number of tubes must be used to cool effectively. But by flattening the tubes, so that the water is carried in thin sheets the cooling surface in proportion to the quantity of water is enormously increased.



THE TUBULAR TYPE OF RADIATOR

This is a design used largely for trucks. The vertical tubes are provided with flanges which increase the cooling area.

It has already been stated that heat always flows from the hotter to the cooler part. So the efficiency of the radiator is greatly increased by soldering sheet

metal fins or flanges on the tubes. Because these are so thin they cool very rapidly, and the heat from the tubes readily flows to them, to be taken up and carried away by the current of air passing through the radiator. At the same time these fins brace and strengthen the tubes, making the radiator much more substantial, without adding greatly to its weight. This plan often disguises a vertical tube radiator so that at first glance it looks almost exactly like the cellular or honeycomb radiator—which will be described later. But a more careful examination will reveal the vertical tubes.

To increase the surface exposed to the air still further, the tubes in some radiators are made to zig-zag downward instead of running straight. Thus it is possible to get into the same height a much greater length of tubing. In a radiator built in this way the flat tubes are so formed that the angles of one tube touch the angles in the next, and at the contact points they are soldered together, making the radiator much stiffer.

Instead of flattening out a round tube and bending it to the desired zig-zag it is usual to build up the tubes of strips of sheet metal soldered together. This practice has led to the designing of a great variety of forms of water spaces and air passages between them.

The Honeycomb Radiator.

The true honeycomb or cellular radiator is built in a different way altogether. Or, rather, it is built on a different principle and in a variety of ways. The radiator is built up of short tubes, which are placed horizontally, extending from the front to the back of the radiator. The tubes are enlarged at the ends, so that when they are laid together they touch only at the ends, being separated between. The ends are all soldered together, front and back, so that the result is a labyrinth of narrow spaces between the tubes with free communication from top to bottom, and these spaces are filled by the cooling water. The enlarged ends of the tubes and the soldering front and back prevent the escape of water between the tube ends. The air passes through the interiors of the tubes. Tubes of various shapes are used—round, square, hexagonal and fluted. The basic principle is the same throughout. In all cases the water spaces open into the tanks or headers at top and bottom and are closed at the sides by metal casings.

All radiators are protected by an outer casing which covers all but the actual radiating surface and by means of which the radiator is held in place on the car. The radiating part is called the core. Between the core and the casing elastic pads are often introduced to cushion

the core and prevent rattling. In trucks the whole radiator is frequently carried on springs to protect it from vibration.

What the "Overflow Pipe" is for.

In every radiator there is a small pipe leading from the inside of the filler to the outside of the radiator at the bottom. This is commonly called the overflow pipe. The real purpose, however, is to carry off steam when the radiator gets hot, and so avoid the raising of pressure which would otherwise cause the radiator to burst. The fact that water overflows through this pipe when the radiator is overfilled, or when a full radiator is shaken by road vibration, is merely incidental.

Obviously it is exceedingly important that this pipe should be kept clear. A clogged pipe would result in "getting up steam" the first time the water boiled, and the pressure would either blow the obstruction from the pipe or open the joints and cause leakage.

The Drain-cock.

A cock is placed at the lowest possible point in the radiator to drain off water when necessary. It is a good idea to open this occasionally and make sure that it is not clogged by sediment. If it is, it is readily cleaned by running a wire through it. Let the water run until the sediment has run off. If the cock is allowed to remain clogged it may fail to work some cold night when it is desired to drain the radiator to prevent freezing.

Circulating Pumps.

Circulating pumps in automobile service are always rotating pumps, as distinguished from the plunger or reciprocating pumps often used in marine and stationary engines. The usual pump is a centrifugal pump and consists essentially of a rapidly revolving wheel with vanes or paddles. Water is led to the center of the wheel and is thrown outward by centrifugal force to the outlet at the circumference of the housing. The revolving wheel is made in a great variety of forms, but the principle is always the same.

The gear pump is also used, and this is precisely similar to the gear pump used for the circulation of oil and described and illustrated in Chapter I. The gear pump is more positive in action than the centrifugal pump, though the advantage is not of great moment.

Drive is from an auxiliary shaft, such as the magneto shaft or the generator shaft, and occasionally the pump is mounted so that it can be driven by an extension of the fan shaft.

How to Care for Pump-shaft Packing.

Where the driving shaft passes through the pump casing there is a packing or stuffing-box just like the packing used on an ordinary water faucet. This packing must be kept tight enough so that water will not leak out around the shaft, but it should not be made any tighter than is necessary. Too tight a packing will wear faster than it should, and imposes unnecessary strain.

There are three parts to the stuffing-box. The gland is part of the pump housing and forms a bearing for the shaft. The outer end is recessed, forming a sort of jacket space around the shaft. Into this annular space the packing is pressed. The third part is the follower or packing nut, which is a cap screwed on a thread formed on the outside of the gland. Screwing down the packing nut compresses the packing and forces it against both the shaft and the walls of the gland, filling the space completely and preventing leakage.

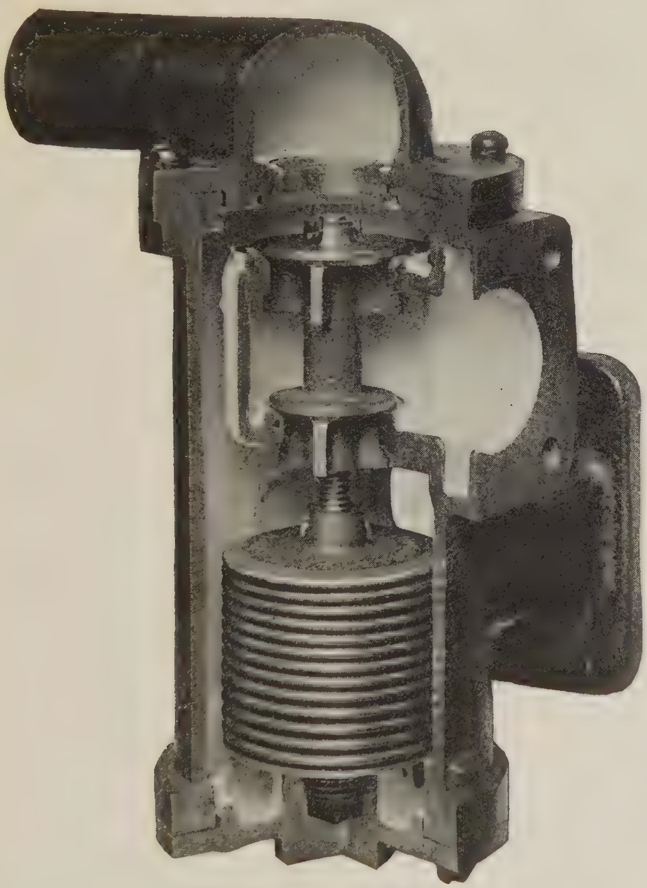
The packing may be one of a variety of materials, the requisite qualities being elasticity, so that the space can be filled by compressing the material, resistance to the action of water, and resistance to wear from the shaft. In all cases the packing is readily renewed. Unscrew the packing nut—be careful to see whether it is in a right- or a left-hand thread—slide it away from the gland and pick out the old packing and put the new in its place and screw the nut back. In the absence of other packing, graphited asbestos string makes a good packing and, in fact, is frequently used. In an emergency ordinary soft wicking can be used. This can be obtained in balls at almost any hardware store and, when well greased, makes fairly good packing. Use plenty of packing—not so much that the nut cannot be screwed well on the gland but not so little that there will be no room left for screwing up when the packing wears.

Temperature Regulation.

Obviously a radiator will cool its water faster on a cold than on a hot day because, as has been explained, the greater the difference between adjoining hot and cold bodies, the more rapidly the heat will flow to the latter. Radiators are so proportioned as to be capable of cooling their engines adequately in the hottest weather, and it follows, therefore, that in cold weather they will cool too much. The temperature at which the engine works is a matter of much importance, and though there is a good deal of difference of opinion among engineers as to just what this should be, there is a good deal of difference in the running of an engine that is too hot or too cold and one that is at the right temperature. Of course too hot an engine will impair its lubri-

cating oil and tend to expand the pistons and rings, while too cold an engine will not have its normal snap and vim, will not pick up as it should and will condense some of its fuel, the heavier parts of which will work down into the lubricating oil and dilute it.

Automatic devices are used with marked success to keep the engine always at its normal temperature when running, and to shorten the time required for warming up in starting. The idea is to prevent the water from circulating through the radiator while it is cold, to allow full and free circulation when maximum cooling effect is required and, in the intermediate stages, to allow just enough water to go through the radiator to maintain the proper temperature.



INTERIOR OF A THERMOSTAT

The expansion and contraction of the bellows-like arrangement opens and closes a valve which controls the flow of cooling water and directs it either through the radiator or back through the engine.

The Thermostat.

The basis of the automatic temperature regulator is the thermostat. In its usual form this is a small bellows-like affair of thin metal con-

taining a liquid that is very sensitive to temperature changes. The thermostat is placed in one of the water passages, surrounded by water, so that it can feel instantly any change in water temperature. When the water is cold the thermostat contracts, and when the water is hot the thermostat expands due to the contraction and the expansion of the liquid. This movement is communicated to a valve. When the thermostat is cold the valve is closed, shutting off the passage of water to the radiator and forcing it to go through a bypass. Thus the water leaves the engine at the bottom only to return directly to it at the top. When the engine is started cold, therefore, the water is not allowed to cool, but is kept circulating around the cylinders, and the result is that the engine warms up in a much shorter time than if it was necessary to warm up the whole body of water and the radiator at the same time. As the engine gets hotter the valve opens a little at a time, and its action is such that the water is kept at the temperature determined by the engine builders as most advantageous. On a very warm day the valve will stand wide open, allowing all the water to pass through the radiator. On a very cold day a comparatively small quantity of water will be allowed to go to the radiator, the rest "short-circuiting" around the engine and keeping it sufficiently hot.

THE RADIATOR SHUTTERS—OPEN

These are similar to the Venetian blind and when in this position do not interfere seriously with the flow of air.

Radiator Shutters.

Much the same effect is produced by the use of shutters over the radiator—a development of the old plan of partly covering the radiator in cold weather. The shutters work like a Venetian blind and are operated by a thermostat or, in some cases, by hand, the driver using his own judgment in the matter.

These automatic devices are in reality very simple and very reliable and rarely give trouble. Follow directions in the instruction book for caring for them and making adjustments; but in case anything goes wrong give the job to someone who knows the work.

The automatic valve interferes with the draining of the cooling system, for when the engine is cool it closes and traps much of the water. Means are therefore provided for opening the valve by hand when draining is necessary. Don't forget this when draining the system to avoid freezing up.

RADIATOR SHUTTERS—CLOSED

When in this position no air can pass through the radiator and the water in the cooling system will retain its heat, or may be brought to the most efficient temperature in a short time.

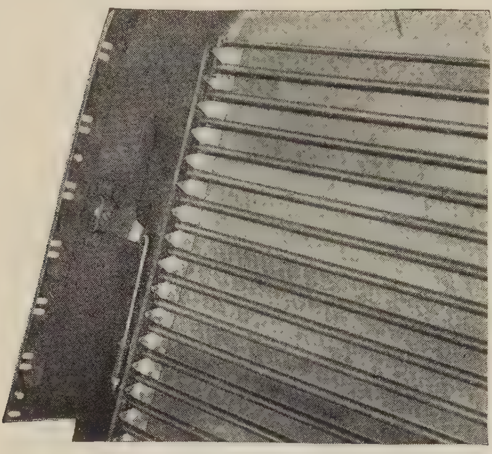
What to Do When the Radiator Leaks.

There is not a great deal that the inexpert man can do when a radiator springs a leak. Leaks may occur where they cannot be reached without special tools wielded with special skill. A cellular radiator can leak only at the ends of the tubes, at the front and back of the radiator, or around the edges of the core, and a little solder applied on the right spot will stop the leak. This kind of soldering, however, is rather ticklish because of the danger of melting the solder already there and so causing more leakage and making the trouble worse than ever. A light copper should be used, and it must be applied with a delicate touch. In case a tube is defective inside, an expert can remove it and put in a new tube. But it takes an expert to do it. Such a leak can be temporarily stopped by plugging the front and back of the leaky tube with corks or wood plugs.

A radiator that springs a number of small leaks is a discouraging thing for the amateur to tackle. It is difficult to locate the leaks exactly and still more difficult to stop them. Let the radiator man have a chance at it.

Often a leaky radiator can be made to hold temporarily by putting

into the water a couple of fistfulls of flaxseed or even cornmeal. There are on the market numerous compounds designed to be put in the water of leaky radiators and to harden as they exude from the leaks, stopping them up. There is a great deal of difference of opinion as to the merits of these things. Instances are on record, however, in which such treatment stopped up the leaks in radiators that would drip themselves empty in twenty-four hours, and no further leakage occurred after several months' service. It is suggested that in using any such compound the stuff be obtained from a reputable maker and that the directions be followed with great care. The radiator should be washed out and made as clean as possible and the compound well mixed with the water, and the motor should be run to keep the mixture stirred up. If the radiator is off, turn it over at short intervals to serve the same purpose.



RADIATOR SHUTTERS, CLOSED—REAR VIEW
The shutters may be operated either by a lever placed on the dash, or by a thermostat placed in the circulating system.

Radiator Hose.

Short pieces of hose are used to connect the engine water pipes with the radiator, because metal pipes would not withstand the vibration. The hose is subject to disintegration from the action of the oil that usually finds its way into the water and from the action of some of the components of anti-freezing solutions, notably glycerin. The hose should be renewed when it shows signs of getting ragged on the inside, for bits may come off and clog the pump, partly stop up the radiator or interfere with the action of the thermostatic water control, where this is fitted. Do not let the hose buckle or partly close up, as this interferes with the free flow of water. If

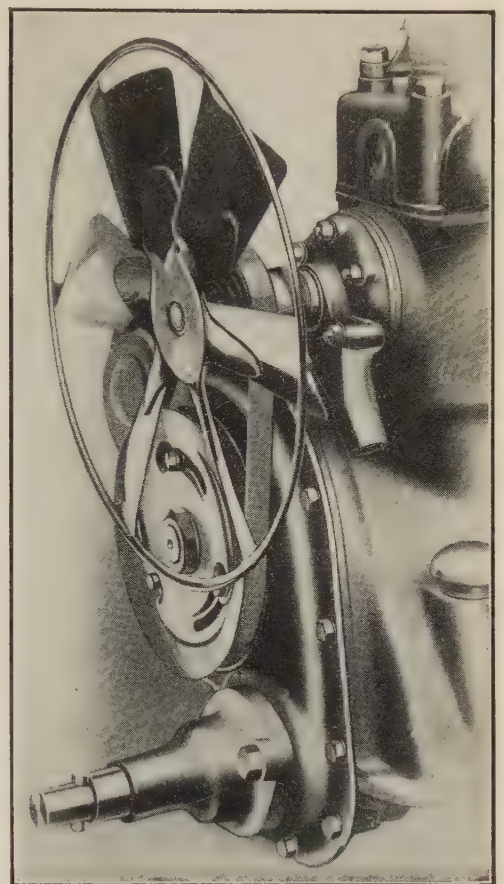
RADIATOR SHUTTERS, OPEN—REAR VIEW
Each shutter is connected with a rod so that all occupy the same relative position.

a hose will not stay in shape put into it a coiled spring that fits closely. This will keep it distended under all conditions.

The clamps used to hold the hose in place are simple affairs and require no explanation. In putting them on, if they are of the kind with overlapping members which slide one upon the other in tightening, tap the band all round with the handle of a hammer or screw-driver when tightening up to ease it into place. This gives more certainty of an equally tight grip at all points in the circle.

How to Care For Fans and Belts.

The fan and its belt are rather hard-worked members. As a rule the fan is mounted on such adequate bearings that it is not likely to give trouble. Its lubrication should not be neglected, however. If a fan-blade is bent it should be restored to form, for if not the full flow of air will be somewhat checked. If there is an automatic spring device to keep the belt tight see that it works freely and does not stick. Do not have the belt any tighter than is necessary to drive the fan without slipping, for unnecessary tension is hard on the bearings as well as the belt itself. A loose belt on a fan without other means for taking up slack is tightened by taking out a piece at the joint and relacing it in the same way as it was laced or fastened before. Be careful, however, about taking up a belt in damp weather. Dampness causes the leather—if it is a leather belt—to lengthen, and when the air becomes dry the belt may be altogether too tight. Allow a little for drying up under these conditions.



HELPING THE AIR TO DO ITS WORK
The fan is driven by the engine and helps give sufficient cooling effect at all speeds of car travel. An inefficient fan or a slipping belt will cause serious overheating.

A little good belt dressing, which is easily obtained, makes the belt grip without excessive tightening, and is a good thing to use. Do not use too much, however, and see that both belt and pulleys are clean

and free from oil when the dressing is applied. Grit and dust cause belts to slip and wear.

Because of the hard conditions under which fan belts work it pays to use the best belts that can be had and to give them a little attention once in a while.

Remedying Cooling System Troubles.

If overheating occurs follow the principle that has been advised throughout—find out positively where the trouble lies before trying to cure it. The cooling system may be entirely innocent. Too rich a mixture, too late a spark, valve trouble, a clogged muffler—all these may be causing the overheating, and not the cooling system.

The first requisite of a cooling system is cleanliness. If the water is not clean, drain it all off and put in fresh water, draining that off again if necessary until the system is clean. Run the engine each time to flush out all parts of the system.

Never put water into an empty cooling system while the engine is hot. The result would probably be a cracked cylinder or water-jacket.

If the system seems very much fouled fill it up with a solution of sal soda and water. Drain this all off immediately after flushing and flush out again with clean water before finally filling up. The solution will eat into paint and varnish, so keep it off the finish of the car.

Sometime the water used contains minerals which are deposited in the radiator and water jackets, or form a sediment. If the radiator is much encrusted there will be sluggishness in cooling and the radiator will not throw out as much heat as it should. The deposits vary greatly with locality and water supply, and no one solvent is good for all of them. A good chemist who knows the local water can tell what to do. In many cases a strong solution of borax is effective.

If one part of a radiator remains cool while the rest is hot it indicates that there is clogging up of some sort.

If the radiator is clean and the whole system heats up, see that the pump is clear. It may be partly clogged up. With the pump working properly and the system clean there should be no trouble.

In a cooling system with a thermostatic control it sometimes happens that the thermostat itself is out of order and is unable to open the valve to allow free circulation. If this is suspected try holding the valve open by the means provided for the purpose. If the system works properly then either the thermostat is not properly adjusted or it is out of order and readjustment or a new thermostat will be required.

It is just as important to keep the outside of the radiator clean

as the inside. Mud and dirt in the tubes will prevent the free flow of air and the rapid transfer of heat.

An effective way to flush out a radiator is to turn a stream of water into it with a hose. Wash out the top part first, inserting the hose in the water pipe, and wash the lower part last.

If the outside of the radiator is very muddy wash it out with a hose, putting an old piece of oil-cloth or anything that will stop the water behind the radiator from reaching the engine. Take particular care not to get any of the electrical apparatus damp.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER VIII

Why cooling is necessary.
How engines are cooled by air.
How engines are cooled by water.
How the water is circulated.
How a thermo-syphon system operates.
How a pump system operates.
How the radiator operates.
How radiators are built.
What the overflow pipe is for.
How to care for the drain-cock.
What kinds of circulating pumps are used.
How pumps are driven.
How pump-shafts are made water-tight.
How to keep the packing tight.
How to repack a stuffing-box.
How temperature is automatically regulated.
How the thermostat works.
How temperature is regulated by shutters.
What to do when the radiator leaks.
How to repair small leaks temporarily.
How to use radiator compounds.
How to apply radiator hose.
How radiator hose becomes defective.
How to keep hose from collapsing.
How to put on hose clamps.
How to care for fans and belts.
How to apply belt dressing.
How to clean out a cooling system.
What to do if the water leaves a deposit.
What to do if a thermostat goes wrong.
How to wash out a radiator.
How to clean the outside of a radiator.

SECTION II. STARTING AND LIGHTING

CHAPTER I

THE BATTERY

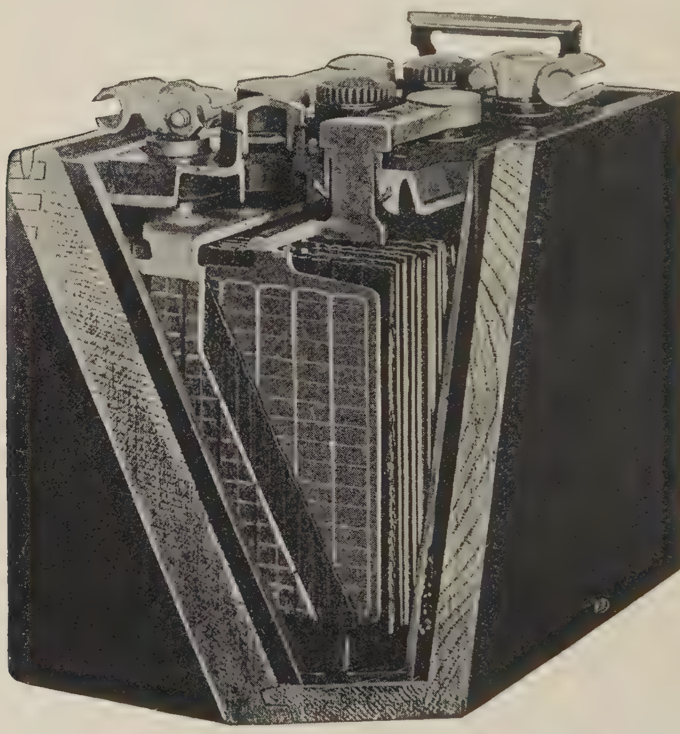
What a Storage Battery Is.

A storage battery is not exactly what the term indicates. That is, it is not merely a tank into which electricity is poured, to be drawn out again as gasoline is handled. The plates and the electrolyte—dilute sulphuric acid—in the battery undergo chemical changes when electricity is passed through them. When connections are made for taking current from the battery the direction of the chemical action is reversed, and current is sent out. In short, the storage battery is altogether a chemical proposition.

Thorough appreciation of this fact will help the user to understand that the storage battery must be treated as a chemical agent rather than a tank.

Possibly a better idea of the function of a storage battery may be obtained by comparing it to a large basin of water provided with holes and stoppers of two or three different sizes. If the water is allowed to flow into this basin in a small stream, it will correspond to the normal charging rate of a battery. If one of the small stoppers is removed, allowing the water to flow out about as fast as it flows in, we have a condition corresponding to the drain represented by the use of the horn and lights, in which the current consumption about equals the charging rate of the battery. If we remove the large drain plug, the water will flow out so much more rapidly than it flows in that it will soon be entirely empty; and this corresponds to the rapid drain due to the continued use of the starter. It is generally considered that the starter consumes from 20 to 30 times the current that is put back into the battery at the normal charging rate. We must keep in mind, however, this fundamental difference between a battery and a basin of water—an empty basin can be refilled in time by the small steady "charging" stream of water; a battery which has been completely emptied by the starter, however, cannot be recharged by the small current received from the generator. The battery will either be worn out, or must be removed and recharged under special conditions.

The battery has been vastly improved since it became an adjunct to the automobile. But the improvements have been almost wholly in matters of detail. The result is that while the old faults of the battery have been pushed a considerable distance into the background, they still exist, for the most part, and will become evident if proper care is not given. There is no disguising the fact that the storage battery, in the hands of the average user, is the weakest link in the



CUT-AWAY SECTION OF A STORAGE BATTERY

The box holding the rubber jars is of wood. The first layer is the jar itself, then comes one of the plates (positive or negative as the case may be), then the separator or a layer of insulating material, and finally the plate the opposite of the first one.

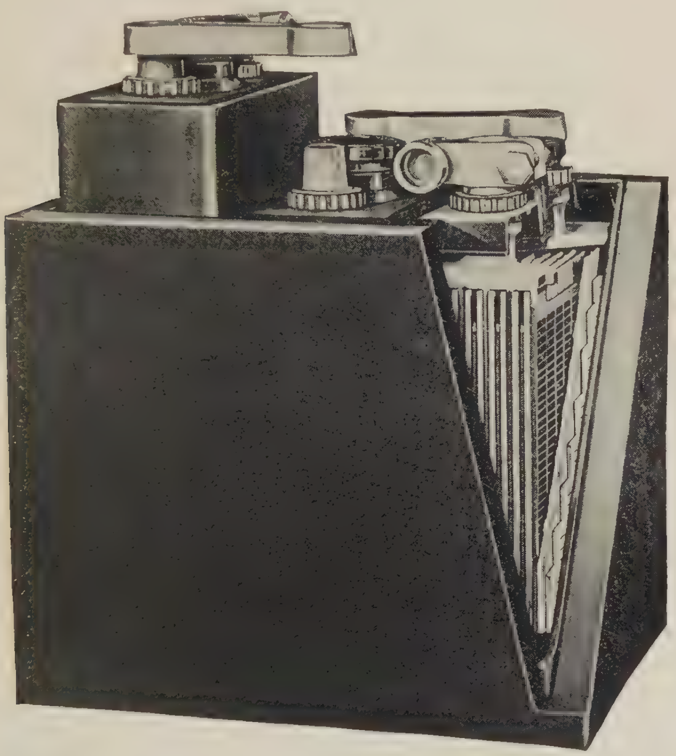
electrical system of the car, and it must be treated accordingly. Yet it is a vital thing, an essential, and its makers have done wonders in bringing it to its present state.

Make up your mind that the storage battery must be given the best possible care if it is to do its normal work. And remember that it is actually given exceedingly hard work under conditions that would have ruined an old-time battery in short order.

TAKE CARE OF YOUR BATTERY.

What the Battery Needs to Keep It In Good Order.

A storage battery will do its best work when it is
Charged at a rate that is not too high.
Discharged—current taken from it—at a rate that is not too high.
Not allowed to discharge below a given point.
Cleaned at proper intervals.
Kept properly filled with electrolyte.



A THREE-CELL (SIX VOLT) STORAGE BATTERY

The plates are raised somewhat above the bottom so that the sediment may accumulate to a considerable depth before the bottoms of the plates are short-circuited and the battery rendered inoperative.

The rate at which the battery is charged may vary considerably without harm; if the generator is running so slowly that it cannot supply sufficient energy to "buck" the battery current, the battery will not charge—just as you cannot force water into a tank if the tank pressure is higher than the pressure of your supply. So an automatic cut-out switch is provided to cut off the generator from the battery when the generator speed falls below the minimum point. At the other extreme, matters are usually taken care of automatically by the winding of generator or by some built-in device which prevents

sending too heavy a current to the battery when the car is running at high speed.

Just here it is well to call attention to the fact that there is a great variety in starting and lighting systems, and each has its peculiar requirements. The user is referred to his instruction book and urged to take particular pains to acquaint himself with the points bearing on the care of the battery and of the appliances for the regulation of battery charging.

The Ammeter.

The guide to the proper action of these appliances is the ammeter on the instrument board. This will show whether the battery is charging or discharging and at what rate. If you know that your battery ought to be charging when the car is running at a given speed, but your meter shows that it is not charging, inspect the system and find the trouble.

The ammeter does not show the current discharge when the engine is being started. The rate is very high, sometimes, in the case of a big engine, running momentarily up to 200 amperes when the starting switch is first closed. One hundred amperes is quite a common rate.

Because of this high rate of discharge it is important to shorten the time during which the starter is used as much as possible. This can be done by taking care that the engine is in good condition, with carburetor properly adjusted, and that everything is in order for easy starting. Release the starting switch the instant the engine takes hold.

Cold Weather Starting.

When starting the engine in cold weather throw the clutch out so the starting motor will not have to turn over the transmission gears. The cold grease in the gearbox is stiff and a very considerable amount of power is required to move the gears through it. This means a heavy additional drain on the battery. A cold engine, with the oil stiff, imposes a heavy pull on the battery at best. The battery is designed to handle this load, but it is so heavy that it should not be increased. Prime the cylinders with raw gasoline of good quality if the engine does not start after a few seconds' use of the starter.

What a Hot Battery Indicates.

Charging or discharging a battery at a high rate raises its temperature. Up to a certain point this does no harm. However, too high a temperature is apt to soften the hard rubber jars. Excessively rapid charging and discharging will disintegrate the plates much more

rapidly than normal use, causing particles of the material with which the plates are filled to flake off and fall to the bottom of the jars.

The battery should never be allowed to get hotter than about 100 degrees. A rough but convenient method of testing temperature is to hold the hand against the jars. The battery should never be much warmer than the hand. If the battery gets hot when on charge see if your instruction book provides for the adjustment of the current to reduce the charging rate. If so, make the necessary adjustment. If not, have recourse to the service station. It is usual, however, to provide an adjustment.

Care of Electrolyte.

The liquid in the battery—electrolyte—must always be over the tops of the plates. Electrolyte levels vary, according to makers' instructions, from just over the tops of the plates to three quarters of an inch above them. If the electrolyte is too low the exposed parts of the plates deteriorate rapidly, and as the capacity of the battery depends upon the plate area in active action, it can readily be seen that the matter is of importance.

The electrolyte evaporates naturally, just as water does, and the rate is accelerated by the warming up of the battery and by the gassing when charging. This evaporation must be replaced with distilled water or rain water.

Do not think that anything that is water will do. Undistilled water contains dissolved matter that is distinctly injurious to the plates and its use is almost certain to lead to deterioration, the rapidity and extent of which will depend upon what the water contains. Any battery station can supply distilled water, and it is cheap.

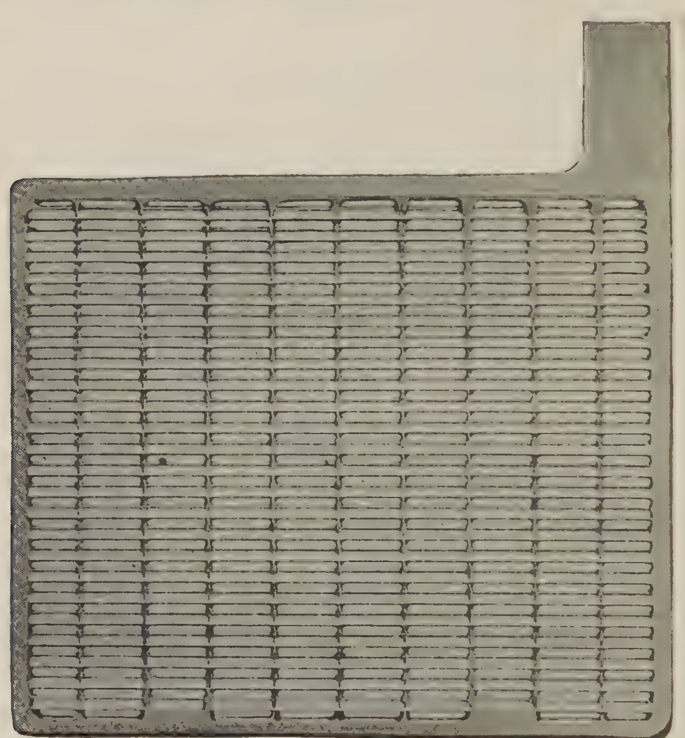
Here is another important point. The acid in the water does not evaporate to any appreciable extent and for this reason only water should be used in "flushing," as filling up to replace evaporation is called. If acid is added it will make the electrolyte too strong and the plates will suffer.

If the electrolyte should be spilled or otherwise lost from the battery and new electrolyte cannot be obtained at once, fill up with water and have new electrolyte put in at a service station at the *earliest possible moment.*

It is not worth while to try to mix your own electrolyte. It is a messy job and if not done right the air will be filled with flying acid that makes nasty burns and goes straight through clothing.

Keeping the Battery Clean.

Because of the extremely corrosive character of sulphuric acid the terminals and wires must be kept as clean as possible. There is nearly always a tendency for the acid to creep out. This can be checked by carefully cleaning the terminals and exposed ends of wires and coating them with vaseline. As a matter of fact, the whole exterior of the battery should be kept perfectly clean because, as has been stated, the acid creeps and makes trouble if allowed to do so.



THE BATTERY GRID OR PLATE

The plates are of lead with the material forming the positive or negative element attached in the form of paste which hardens. When the battery becomes worn out, portions of the paste will be seen to have fallen away.

Occasionally a battery jar develops a leak. A small leak is indicated, if in no other way, by the fact that the leaky cell always requires more water when filling up than the other cells. Sometimes the jar can be repaired and sometimes it cannot. The service station will tell you.

What Sediment Is.

A battery that lives its normal life becomes useless when the active material of the plates has disintegrated and fallen to the bottoms of the jars, leaving but little on the plates. Jars are always made with

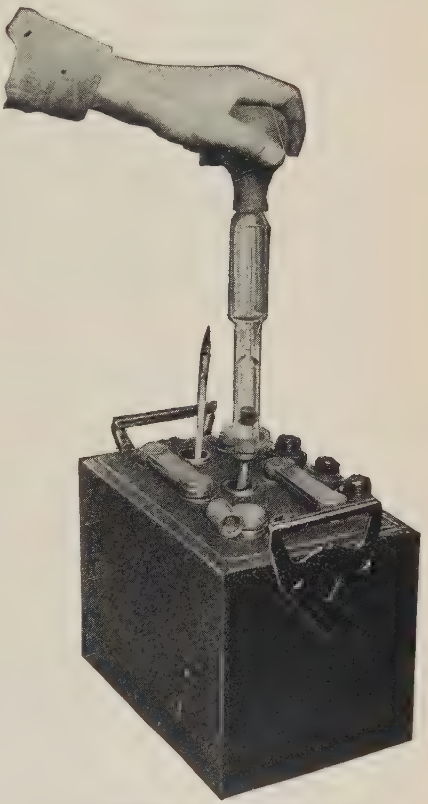
space at the bottom to hold this sediment. Some cells are made with sediment spaces so large that they will hold all the "mud" the plates will drop during their life. Others require more frequent cleaning out, and this cleaning is very necessary. If the sediment rises until it touches the plates there will be internal short-circuiting, heating and much loss of efficiency and shortening of life.

Indications of Battery Condition.

The best indication of battery condition is the hydrometer test. It is well worth while for the user to provide himself with a hydrometer—and note that it should be a good one.

When the battery is *fully charged* the electrolyte should test at least 1250. The highest reading should be about 1280. These figures will vary slightly with different makes of batteries, but are practically correct. Sometimes 1200 is not considered too low.

If you are doubtful of the condition of your battery and want to test it accurately, use a hydrometer and a low-reading voltmeter. Put the battery on charge by running the engine and continue the charge until the gravity ceases to rise, testing the gravity with the hydrometer. If there is no change in gravity between two readings at half-hour intervals the battery has all it will take. If the reading is low you cannot improve matters by continuing the charge unless the plates are sulphated, in which case a long-continued charge at a low rate will in some cases help matters. This, however, is not a job for the average user.



AN IMPORTANT BATTERY TEST

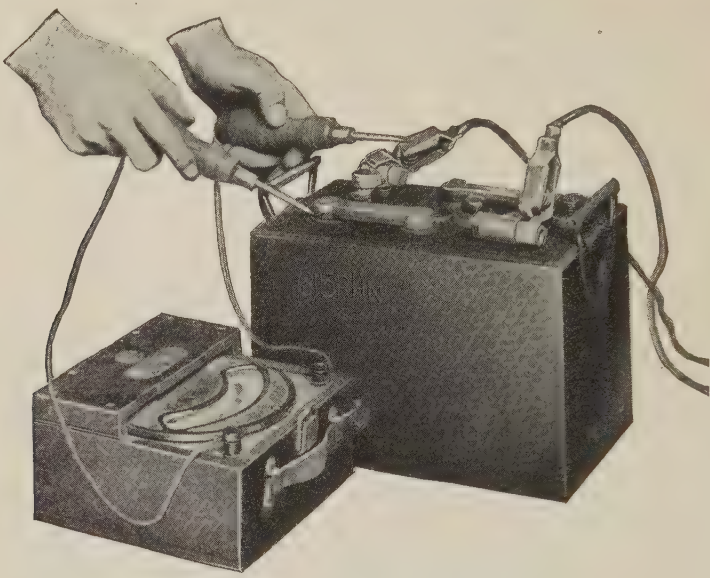
The hydrometer gives the specific gravity of the electrolyte and forms the most accurate method of testing the condition of the battery.

Testing the voltage is a check, in a way, on the hydrometer test. A three-cell battery fully charged will test to from 6.5 to 7.5 volts.

Remember that an open-circuit voltage test is of no value whatever. The voltage must be tested while the battery is doing work, such as starting the engine, the voltmeter being connected in the circuit. The

voltage of a battery that is not giving out current will be about the same whether it is fully charged or nearly discharged.

By using both voltage and hydrometer tests the condition of a bat-



USING THE VOLTMETER

The voltage of a "dead" battery will show nearly as high as one in good condition unless the battery is doing considerable work. The lights, horn or the starter should be used when a voltage test is taken.

tery can be ascertained with certainty. But don't forget that open circuit voltage means nothing and that a hydrometer test of a partly-charged battery is equally useless by itself.

Winter Care of Storage Batteries.

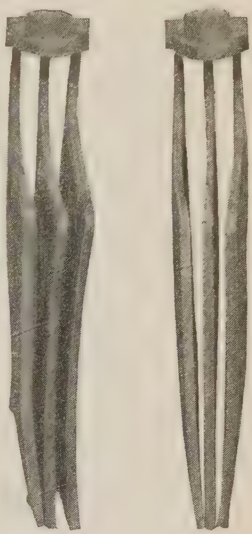
A storage battery left standing for a long period without attention will deteriorate a great deal. If the car is laid up for the winter charge the battery every two weeks by running the engine until the electrolyte in the cells shows 1280 on hydrometer test. If you have no hydrometer run the engine for two or three hours at a speed that would drive the car about 20 miles an hour on the road. This will ensure a sufficient charge. Slow the engine if the battery heats. If it is impracticable to run the engine and you have no other way of charging the battery take it out of the car and hand it over to a battery service station for winter storage. If there is no battery station at hand give the battery to a garage where battery charging is done and arrange to have a charge put in every two weeks.

Neglect of the battery during the winter is responsible for innumer-

able troubles. A battery left in perfect condition in the fall will come out a feeble, inefficient unit and it will never fully regain its efficiency.

A charged battery is very hard to freeze. A discharged battery freezes easily.

Ignition.



BUCKLED PLATES

Plates in this condition which touch at any point throughout their length are practically useless. Buckling is due to too rapid and continued a discharge or charging rate.

With an ample supply of current provided for the starting and lighting of the car it is a simple matter to add the necessary ignition apparatus. This usually takes the form of a combined timer and distributor and a non-vibrator coil. Sometimes the timer-distributor unit is mounted with the generator and sometimes it is separate. The principles are precisely the same as have already been described in the chapter on ignition.

In one of the most popular starting-lighting-ignition systems a set of dry cells is used to furnish ignition current for starting, an automatic switch, however, cutting out the battery and connecting the generator into the circuit when sufficient speed has been attained. The dry cells are used only part of the time, so that they do not run down rapidly. With the dry cells an "ignition relay" is used. This breaks the flow of current immediately after contact has been made by the timer, so that the drain on the battery is much less than if the contacts were allowed their normal period. With current coming from the generator there is no object in rigidly economizing in ignition current, and a rapid series of sparks occurs, while on the dry battery circuit there is a single spark. The relay may need adjustment occasionally.

Adjustment is readily made when the engine is running on the battery by turning the adjusting head in a counter-clockwise direction until the engine stops firing, and then turning it five notches in the opposite direction.

Never turn the head more than is absolutely necessary in either direction. This is important.

Keep the contacts clean, and the timer contacts also. If the armature action is weak despite proper adjustment it means that the dry cells are weak or that there is dirt on the relay or the timer contacts.

When a timer of ordinary construction stops with the circuit closed—that is, with the arm or cam making contact—there will be a continuous flow of current from the battery, unless some means is taken to stop

it, and exhaustion would soon follow. In many cases this is provided against by the use of a resistance coil. This consists of a coil of wire of a metal which offers considerable resistance to the flow of current.

This coil is so proportioned that it does not interfere with the passage of the normal current. If the timer stops on contact, however, the heavy flow of current causes the coil to heat up, and the hotter it gets the more slowly current flows.

Occasionally this wire breaks or burns out, and in case of interruption of the ignition circuit it should be examined.

An ingenious method is used in one popular ignition system for cutting off the current if the timer stops on a contact. The path of the current leads through a thermostat, which is simply a strip of metal that bends when heated. The normal flow of current does not heat the thermostat. But if the timer stops on a contact the abnormal flow of current heats the thermostat and it bends until it makes contact and causes current to pass through a device that is similar to an electric bell. The hammer vibrates, just as does the bell hammer, and strikes a trigger which releases the switch and turns off. This device will operate in from half a minute to three or four minutes after the engine stops. This switch is illustrated in Chapter 6, dealing with ignition.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER I, SECTION II

What a storage battery is.

Why the storage battery needs exceptional care.

What prevents a battery from doing good work.

How automatic battery charging is regulated.

Why a cold engine is hard on the battery.

Why the instruction book should be studied.

Why engine condition is important with reference to the service of the battery.

What causes a battery to heat, and how to know when it is too hot.

What electrolyte is.

How to take care of the electrolyte.

How to prevent corrosion of battery terminals.

How to detect battery jar leaks.

How to test battery condition.

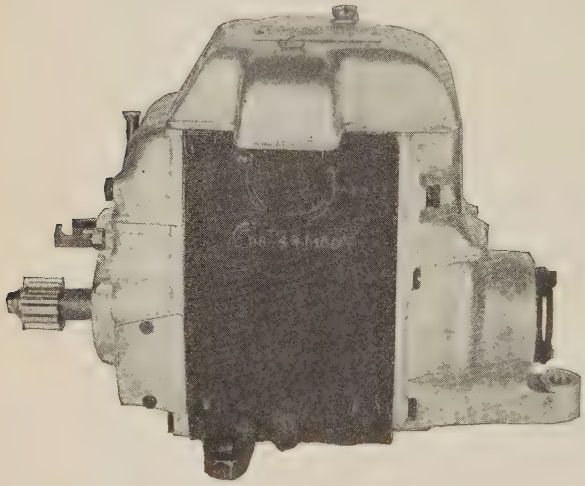
How to use the hydrometer and volt-meter.

CHAPTER II

THE GENERATOR AND STARTER

Similarity of Motors and Generators.

There is practically no difference between an electric motor and an electric generator or dynamo. Feed electric current to a motor and it will run and deliver power. Drive the same motor by chain or gearing and it will generate current. This fact is taken advantage of in "single-unit" systems, in which the same machine is used for cranking the engine and, after the engine is started, for generating current for charging the battery. "Two-unit" systems use a separate generator and motor. Each plan has advantages and disadvantages and each is widely used.



A MOTOR-GENERATOR SYSTEM

The motor and generator are so nearly the same that when the former is run under power it will generate current, or when the current is led to the latter it will develop power.

Whether there be a separate generator and motor, or a motor-generator, as the two-purpose machine is termed, the principal parts are alike. The rotating part is the armature, and this is fixed on the shaft. The armature windings are connected with the copper bars of the commutator, which, in turn, are connected with other parts of the system by means of carbon brushes, which are stationary and therefore have sliding contact with the commutator. The armature revolves between iron or steel pole-pieces, which are extensions of the cores upon which the "field-magnet" windings are placed. The armature is just as close to the pole-pieces as it is possible to get it, for the closer it runs the better the results. The whole machine is enclosed in a casing, part of which forms the frame supporting the field magnets and the bearings.

Starting-lighting Troubles.

Starting-lighting system troubles divide themselves naturally into two main classes—insufficient current, on the one hand, and disorders that prevent the use of current on the other hand.

In a majority of cases lack of current is due to storage battery trouble, and a car with its battery kept in the best possible condition will as a rule have little electrical trouble.

Among the troubles that prevent the proper flow of current perhaps the most common is brush trouble, and in many cases this is simply due to the brushes being held off the commutator, so that there is no

A MOTOR OF THE TWO-UNIT TYPE

In this system the motor is used only to drive the engine when starting, while the generator is a separate machine which develops the current.

contact, or too light a contact. Every user of a car has heard of "sticking brushes." A brush lifted from the commutator is like a water pipe disconnected and plugged tight at the ends—the line goes out of business.

If the starter will not do its work despite the good condition of the battery, remove the cover over the brush holders and press down the brushes—gently—with your fingers while some one presses the starting button or pedal. If the starter works properly then it is proof that the brushes had not been making proper contact. The most likely fault is that the springs are weak, though occasionally the brushes may be held up by stiff joints, or by failing to slide in their holders.

All "brush rigging" is alike in principle, though there is much difference in the details of different makes. There is a holder that keeps the brush in place and there is a spring to press the brush on the commutator. Examine the machine and move the brushes up and down a little and you will see just how it works. The brushes should return to contact with the commutator with perfect freedom. If there seems to be ample spring pressure, yet the brushes move back sluggishly, it may be that there is a tight joint. See where the joints are and apply a very small drop of oil, taking the greatest care not to get any on the

commutator. Wipe off any oil that may be left outside. If the springs are weak the service station will tighten them in a jiffy, and it is best to let the expert do this, for too much brush tension causes rapid wear of brushes and commutator.

In time the brushes will wear down until they are too short to make good contact. Look out for this if the machine has been running for some time. New brushes must be put in.

Invariably use the brushes made especially for your machine. It is vital that the brushes should be exactly right, and you can't afford to take any chances.

Some brushes are fitted with short flexible cables called "pigtails" which are held by screws provided for the purpose. Always see that the pigtails are connected up and that they are put in just as the old ones were.

Care of Commutators.

The commutator is made up of a series of copper bars, each bar connected with a section of the armature winding and each bar insulated from the bars on either side of it. It is extremely important that the surface of the commutator should be as nearly perfect as possible.

Never under any circumstances put oil on the commutator. It will ruin it.

A commutator in good shape will have a dark brown or bluish glaze. This is the ideal working surface.

Do not think that the surface should be the color of bright, clean copper. If there is a raw copper surface it indicates abrasion and rapid wear. The cause will be found in too heavy a spring pressure, grit and dirt on the brushes or something that abrades the copper.

Of course the commutator will wear in time. The copper wears a little faster than the insulating material between the bars, and then the insulation is left projecting slightly, causing the brushes to hop up and down a little and spark. The sparking blackens the commutator and causes a deposit that very soon causes trouble and interferes seriously with the working of the machine.

There is a good deal of difference between the appearance of a commutator that is suffering from high insulation and one that is merely dirty, though one may produce about the same effect as the other, so far as running is concerned. Blackening from high insulation is usually indicated in its early stages by black streaks parallel with the bars. The leading edge of a blackened bar—that is, the foremost edge as the commutator turns—will be blackened first, while the back edge may

be clean. A dirty commutator will be streaked around the circumference, in most cases.

If the commutator is dirty, try wiping it off with a rag and a very little gasoline. If this does not work, sandpaper it.

Do not use emery cloth or emery paper.

Use a strip of very fine sandpaper—about No. 00—at least as wide as the brushes and wrap it so that it covers a full half of the circumference. Stop sandpapering when the dirt is off; in other words, do not wear down the copper unnecessarily. After sandpapering clean out all dust and grit very carefully.

If the commutator is sufficiently accessible, an excellent way to sandpaper it is to have a block of wood hollowed out in a half circle a little larger in diameter than the commutator; line it with a piece of thick felt and lay sandpaper on the felt. This does a fine job. Always leave the commutator as smooth as possible, finishing with a piece of fine sandpaper that is so worn that there is practically no cut or scratch left in it. Remember that the copper is soft and very easily cut.

Do not sandpaper the commutator unless it cannot be made clean in any other way. This is because the old working surface is better than a new surface, and if it can be preserved so much the better.

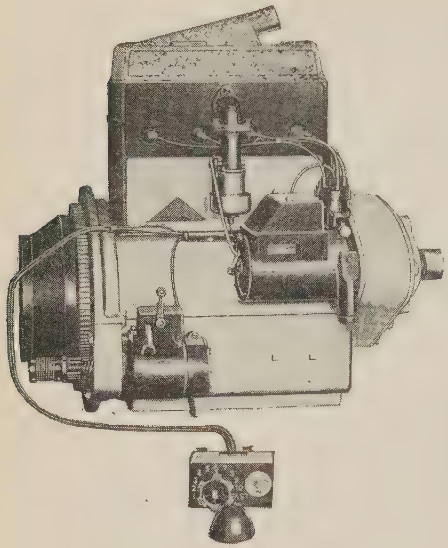
Many commutators are made with "undercut" insulation. That is, the insulation between the bars is cut out below the level of the working surface so that the commutator will have to wear considerably before there will be high insulation. When the bars wear down, however, and the insulation begins to get high, have the service station do the undercutting. It can be done by an owner who is fairly expert with tools, but it is a job that requires much care. The insulation must be cut out cleanly from bar to bar, making a groove about half as deep as it is wide. The copper must not be cut and great care must be taken not to mar the edges of the bars. The groove may be started with a fine triangular file and finished with a piece of hacksaw blade—one with fine teeth—set in a handle.

Fitting New Brushes.

If you put in your own new brushes you will have to fit them to the commutator. As they come from the maker they are usually square on the ends, whereas they must be curved to the same radius as the commutator to work properly. Rough out the curve in the contact end of each brush with a half-round file. Then put the brush in place, put under it—between brush and commutator—a strip of fine sandpaper a little wider than the brush and draw it back and forth until the curve

is perfect. Take care that the sandpaper strip is carried far enough around the commutator to give the true curve; if it is not carried round far enough the edges of the brush will not make contact.

Commutators on both generators and starting motors, where there are both, call for precisely the same treatment and are subject to precisely the same troubles. The generator commutator will wear more rapidly than the other because it is in use so much more but, on the other hand, its brushes are not so likely to stick because of constant use. They will occasionally stick, however, and of course the generation of current will be interfered with or stopped, according to the extent of the trouble.



A TWO-UNIT SYSTEM INSTALLED

The instrument shown at the lower left-hand side of the engine base is the starting motor which meshes with the teeth on the fly-wheel. The instrument above it to the right is the generator driven by the engine.

Short Circuits.

Grounds and short circuits may occur in the starting-lighting wiring, and the principles are precisely the same as in the case of ignition wiring. Take particular care that all connections are clean and firmly made, for the voltage, or pressure, is low and the current is easily interrupted by dirt or an exceedingly small air gap. A method for testing for grounds and shorts is described later.

Suggestions for Avoiding Trouble.

Never run the engine with the generator disconnected from the battery unless the generator is disconnected from the engine so that its armature will not be rotated—unless specific instructions are given in your instruction book for so doing.

Keep a chain drive well oiled and let the chain run a trifle slack rather than too tight. It will run more quietly and last longer in this way.

Moving the car with the starting motor imposes a terrific strain on the battery. It is an abuse. Don't do it.

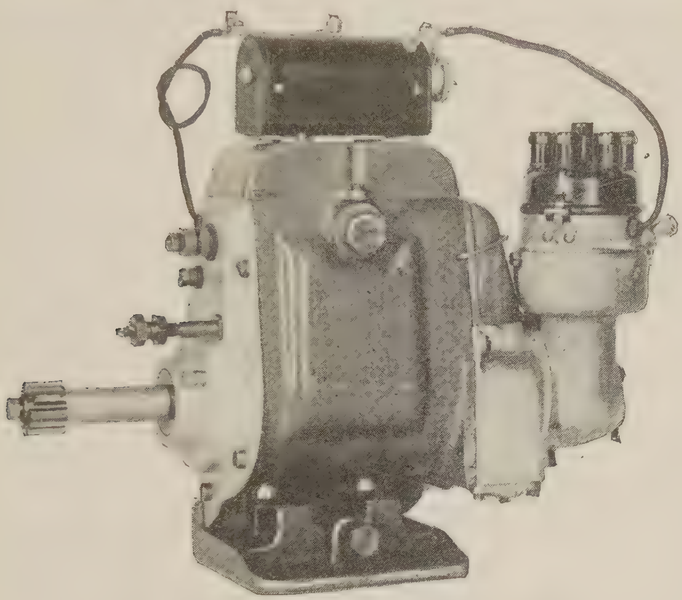
Keep commutators, brushes and brush rigging free from oil and grease—scrupulously.

Keep all electrical apparatus perfectly dry. Don't let it get splashed when washing the car.

The circuit-breaker, which connects and disconnects the generator and battery automatically, should not be tampered with. If you are convinced that it needs attention, let an expert do it.

If it is necessary to remove any part of the electrical apparatus or make adjustments, first disconnect the battery, which is most conveniently done by removing the ground wire from its ground connection.

If the system is in good order mechanically, but the motor will not turn the engine over, don't keep on trying. In all probability the battery is almost exhausted, and it must be recharged. Overdischarging is very hard on the plates and shortens their period of activity.



A COMPLETE IGNITION AND STARTING OUTFIT

The ignition coil, timer and distributor are mounted on the motor-generator frame. The outfit is driven by the gasoline engine, contact with the fly-wheel being made automatically when it is desired to start the car.

Don't lay tools, pieces of wire or carbon or other conductors on top of the battery. In fact, don't lay anything on the battery. A "dead short circuit" across the battery terminals will destroy the battery in a very brief time.

Be absolutely certain that you make connections at the right places, if you should have to disconnect anything. A wrong connection may ruin a battery or generator or other expensive component.

A battery that has been used for some time and then allowed to stand will recuperate somewhat. Do not depend upon this, however, for it does not amount to much. Recharge the battery if it is low.

Release the starting switch as soon as the engine starts. There is

nothing to gain and there may be a good deal to lose by keeping the switch "on" after the engine is running.

A great many starting systems use a gear sliding on a shaft for engagement with the large gear on the flywheel for starting. See that the sliding gear—whether it slides on a plain shaft or on a threaded shaft—moves freely. There is liability to clogging from gummed oil, and this should be loosened up with kerosene occasionally.

Starting-lighting systems are well and substantially built, and liability to get out of order is as small as it seems possible to make it. But trouble can occur. Remember that if the system is kept in good order in all its details it will do its work. Try to understand the main points of your system and learn how things work—which involves an understanding of why they do not work if they fail. Apply the proverbial ounce of prevention and you will have little to do in the way of curing. But don't attempt to do a thing you don't know anything about. Find out about it first.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER II, SECTION II

Why generators and starting motors are similar.

What the principal starting-lighting troubles are.

How to find and remedy stuck brushes.

Why brushes are important.

What "pigtails" are.

How to keep the commutator in good condition.

How to know a good commutator surface.

What causes "high insulation."

How high insulation is remedied.

What "undercutting" is and how it is done.

How to sandpaper a commutator.

How to make a sandpapering block.

How to fit new brushes, and why they must be fitted.

How to guard against grounds and short circuits.

How to avoid troubles in the electrical system.

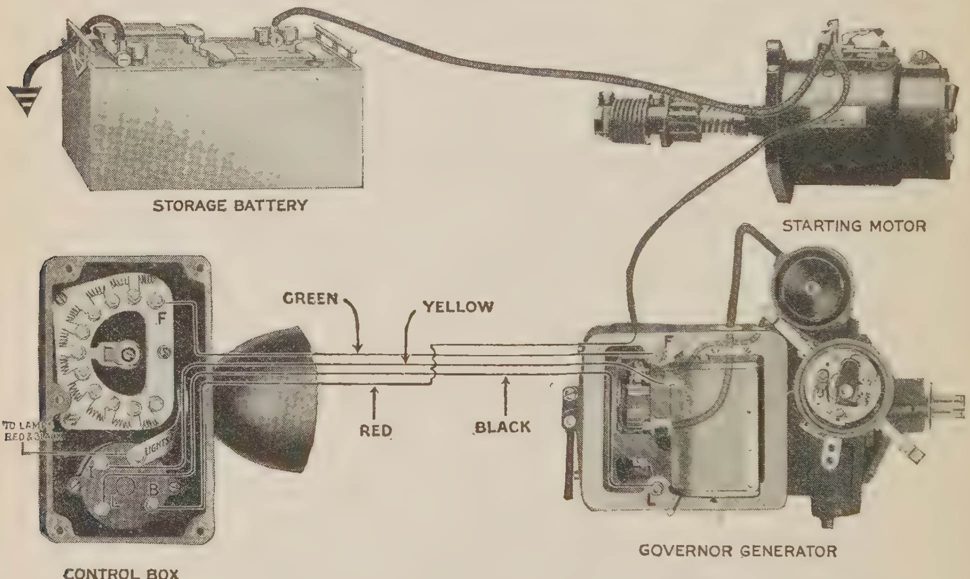
How to care for sliding starting gears.

CHAPTER III

BULBS AND WIRING

Lighting System Troubles.

In looking for sources of trouble in the lighting system bear in mind the fact that the electrical principles are fundamentally the same as those described in the chapter on ignition. No high-tension current is used, however, so there is no such danger from leakage. On the other hand, however, the low-tension current is more easily interrupted, as has already been stated, than high-tension current, and for this reason



A TYPICAL STARTING AND LIGHTING SYSTEM

There may be as many different wiring diagrams as there are cars on the market. Each system will vary in detail, but the instruction books should contain a complete description of the system concerned.

good contacts and clean contacts are important. This is a point of such moment that it is worth repeating. In a great many cases of lighting trouble there is nothing wrong except that something in some part of the system has occurred to prevent, or partially prevent, the flow of current.

The lighting wiring is separate from the starting wiring. The latter carries a very heavy current, and it is usual to run wires direct from

the battery to the starting motor, or the motor-generator, as the case may be. As a rule these wires are readily distinguishable because of their size.

A wiring diagram looks complex, and is complex, to the uninitiated. But it need have no terrors, for the wires are always well protected and are not likely to give trouble. This does not mean that they should not be inspected occasionally, for it is the unexpected that happens sometimes. The first places to look for troubles are terminals, moving contacts of any kind, lamps and lamp connections. The battery, having been referred to at some length, may be considered disposed of in this case, though it is well to say that if the lamps burn dimly it is advisable to be very sure that the battery is all right before assuming that something else is wrong.

If the lamps burn brightly when first turned on and soon grow dim, it indicates clearly an exhausted battery. As has been stated, the battery, after standing for a while, recuperates a little and will for a short time, perhaps, give sufficient current. This, however, will not last long. If the battery is very low the lamps may burn more or less dimly at first and then gradually fade out. The remedy is obvious.

Most systems are so arranged that the lamps take current from the battery when the engine is not running or when it is running slowly but when speed increases the current is taken from the generator, an automatic switch making the change at the proper point. As a rule the lamps burn a little brighter when the dynamo current is supplying them; the change can be observed if the lamps are watched while the engine speed is increased. If there is a very marked difference between the brightness when on battery and on generator circuit; the battery is most likely low, or else the automatic switch is not working properly.

Cause of Dim Lamps.

If the lamps burn brightly when the engine is idle and dim excessively when the starting switch is operated, it indicates a weak battery or a loose connection or that the engine is so stiff that it requires an abnormal amount of current to start it. If this is suspected try the engine with the hand crank to see if it is stiff.

If lamps fail to light or if they go out suddenly, look for burned-out fuses, loose connections in wiring or the lamp bulb may not be making good connection in its socket. The lamp itself may be burned out; this is easily tested by trying a new bulb.

If a lamp flickers there may be a loose connection somewhere or the bulb may be loose in the socket.

Focusing Headlights.

If the headlights are not properly in focus the illumination of the road will be poor, even if the lamps are burning at full brightness. In every headlight there is a certain position for the bulb where its light will be thrown out by the reflector to the best advantage. Means are usually provided for adjusting the focus. Place the car where the light from the lamps will be thrown on a wall or fence about 10 feet away and adjust the bulb until the dark rings disappear. Often it is necessary to readjust the focus when putting in new bulbs because the filaments are not always in precisely the same relative position in bulbs. Set the lamps so that the light will be thrown down on the road so you can see where you are going. Light thrown into the air does you no good.

Use and Care of Bulbs.

The most important thing about bulbs is to use the right ones. Be particularly careful to see that the voltage is right. A bulb made for a higher voltage than that of the lighting system will burn dimly. A bulb made for a lower voltage will burn with great intensity and then burn out. The length of time it requires to burn out will depend upon how much higher the voltage is than that for which the lamp was made. If there is much difference the lamp will burn out immediately.

The higher the *candlepower* of the lamp the more current it will take and the greater will be the drain on the battery.

Do not use lamps of higher candlepower than those specified for your system, and do not use lamps of a different voltage than is specified.

A bulb that is allowed to get very dirty will burn out sooner than one that is kept clean because it cannot radiate its heat as rapidly as it should. Also, a dirty bulb is an inefficient source of light. So keep the bulbs clean.

Care of Reflectors and Lenses.

The condition of the reflectors is of importance. Keep them clean and bright. A silver-plated reflector must be treated carefully, for the silver is very soft and easily scratched. If the silver is much tarnished clean it with soft chamois and a little jewelers' rouge dampened with alcohol. Then use another piece of chamois with a little dry rouge. This will give a brilliant surface. Don't rub too hard, for the silver is easily worn off. In time the original brightness will wear away and the reflector will have to be re-plated.

Keep the lenses clean. Do not think that because glass is very hard it cannot be scratched easily. It can. A dusty, gritty cloth will scratch

a lens and dim its high polish. High-grade lenses are of a rather soft glass and should be treated with respect. Keep special pieces of soft cloth and chamois for lamp work, and see that they are kept free of dust and that they are not used for anything but the lamps.

One-wire and Two-wire Systems.

Some lighting system are designed on the one-wire and others on the two-wire principle. This means simply that in the one-wire system the return current to the battery is grounded, just as ignition current is grounded. The principle is precisely the same. In the two-wire system both sides of the circuit are wired. Both systems are satisfactory and give good results.

One-unit and two-unit systems must not be confused with one-wire and two-wire systems. The one-unit system, or single-unit, uses a single machine for both motor and generator, while in the two-unit system there are two separate machines, one a motor and the other a generator. Either single or double wiring may be used with either single or double unit systems.

What Fuses Are.

Fuses are short strips or wires of a metal that melts easily. They are inserted in the various circuits for the protection of the lamps, windings and other parts. If for any reason the current in any circuit becomes so heavy as to endanger the apparatus, the fuse melts—"burns out" or "blows"—and saves damage. Fuses vary in form, in location and in number in various systems, but always are placed where they are easily inspected and renewed.

If a fuse burns out it puts the circuit of which it forms a part out of business until a new fuse is inserted. So, in case of an interrupted circuit, do not forget to inspect the fuses.

When a fuse burns out, find out why it burned out before putting in a new one. If the trouble remains you will only burn out another fuse, and if you keep on that way you may manage to do damage.

A short circuit, in a lamp circuit will usually cause the fuse to burn out or blow, because, the resistance of the lamp being eliminated, too heavy a current will flow. Look for grounds, especially in a single-wire system.

Using a Test Lamp.

The easiest way to detect a ground or a short-circuit is to use a test lamp. This is simply a small lamp, such as is used in the lighting system of the car, with two wires attached, having the ends bare.

If a fuse is blown in a single-wire system and a ground or short cir-

cuit cannot be seen, make a test with the test lamp with no fuse in place in the circuit in which the fuse has blown. Turn on the lighting switch. Touch one test lamp wire to one of the fuse clips and the other wire to the other clip of the same fuse. If the test lamp burns brightly it indicates that the wire leading from the fuse to the lamp is grounded, and the job is to find the ground and remove it. If both test lamp and car lamp burn at the same time it indicates that the wire is not grounded.

To test for a short circuit that cannot be found otherwise, disconnect the negative terminal of the battery (marked Neg. or—) and connect one end of the test lamp wire to the negative battery terminal and the other to the cable that has been removed.

Turn off the lighting switch before doing this.

If the test lamp burns it indicates that there is a ground or short circuit. Otherwise it would not burn with the switch turned off. Go over the wiring carefully, with the lamp burning. Move the wires about. When the grounded or shorted wire is moved out of contact the lamp will go out, and you will know where to look for the trouble.

If these simple tests do not reveal the trouble let the service station have the job.

Anything that causes a disconnection and prevents the flow of current is an open circuit. A broken wire or a wire adrift from its connection causes an open circuit, for instance.

Open circuits are not likely to occur except from looseness of things that should be tight. Wires are not easily broken, as a rule. Of course a blown fuse causes an open circuit.

The test lamp can be used to hunt out open circuits. The method of using it will depend on the lighting system, and the instruction book will tell just what to do.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER III, SECTION II

How to look for lighting troubles.

How to focus headlights.

What lamp bulbs should be used.

Why bulbs burn out.

Why bulbs should be kept clean.

Why using wrong bulbs makes trouble.

How to care for reflectors and lenses.

How to keep reflectors bright.

What one-wire and two-wire systems are.

What fuses are.

Why fuses burn out.

How to use a test lamp.

SECTION III. THE TRANSMISSION SYSTEM

CHAPTER I

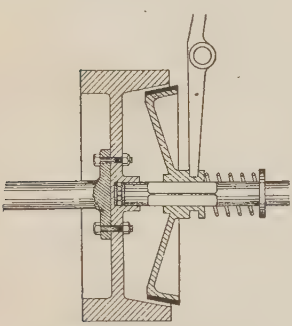
CLUTCHES

Why an Automobile Needs a Clutch.

A clutch is necessary on a gasoline car because it is necessary to allow the engine to gain speed before making it drive the car. It is necessary to allow it to gain speed because at low speed it has very little power. In other words, its power is dependent upon its speed; the lower the speed the lower the power. So the engine must be started without load, and the load applied after it gets going at sufficient speed to carry the load of starting the machine.

Types of Clutches.

Clutches are divided into two main groups—cone clutches and disc clutches, both of which are made in a wide variety of designs. Other types have been used in the past but have been discarded, so far as automobile service is concerned.



THE CONE CLUTCH

The cone with its leather-lined surface (shown in black), is about to engage in its corresponding recess in the flywheel.

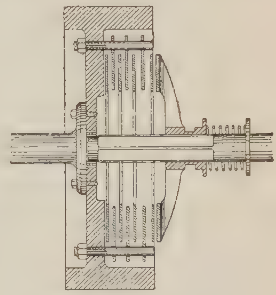
The cone clutch, reduced to its elements, is simply a short section of a cone of large diameter fitting into a recess of precisely the same form and pressed into place by a spring. The internal member is usually cut in the flywheel, or attached to it, while the external member is separate and is the part that is moved in engaging and disengaging. A heavy spring presses the clutch into engagement and pressure on a pedal releases the spring. The holding power of the clutch—its ability to drive without slipping when under full spring pressure—is due to two things. One is friction and the other is the wedging action due to the conical shape. The friction is made high by lining one of the members—usually the moving part—with leather or with fabric similar to brake lining.

The angle of the cone is very carefully worked out. If it were too

slight the clutch would "grab" or wedge hard into place as soon as let in, and the car would start with a violent jerk and the engine might be stalled. If the angle were too great—the slope too abrupt—there would be insufficient wedging action and the clutch would slip when it ought to be driving without slipping.

In the ordinary type of cone clutch the cone moves toward the flywheel into engagement. Occasionally this order is reversed, and the cone moves in the opposite direction, engaging with an internal member bolted to the flywheel. This is called a reversed cone clutch. The spring is placed between the flywheel and the cone. The principle is precisely the same, however, as that of the ordinary cone clutch.

The disc clutch depends wholly upon friction, there being no wedging. It consists of a series of discs, half of which are attached to driving members attached to the flywheel and the other half to the shaft which transmits power to the gearset. The discs are so arranged that they can be pressed tightly together by a spring or springs, but when the spring pressure is released they will move apart slightly. When pressed together the friction is so great that the set of plates attached to the flywheel is firmly clamped to the set attached to the shaft, and a positive drive is effected. In some cases all the plates are of metal, and the engaging surfaces are metal-to-metal. In others half of the plates are faced with friction fabric. Some clutches run in a bath of oil and some run dry.



THE DISC CLUTCH

Alternate plates are attached to the fly-wheel and those in between are connected with the gearset shaft, so that when the entire mass is compressed all revolve as a unit.

A popular type of clutch is the plate clutch, which is simply a disc clutch with only three plates. This is a simple and compact form and is quite widely used.

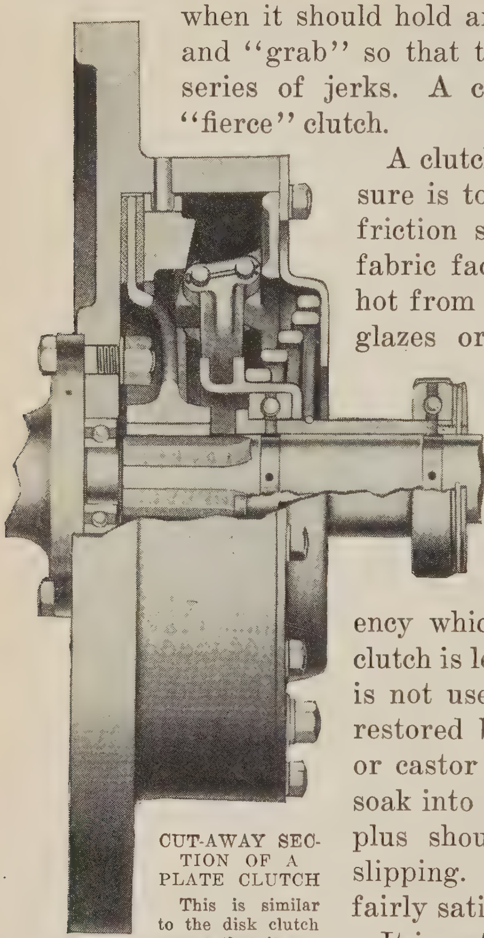
In some disc clutches "cork inserts" are used instead of fabric facing. These are simply small discs of cork set into the discs, projecting slightly above the metal surface. When the discs come together the cork engages first and gives an easy engagement. The action of cork is peculiar. Though very soft, the cork does not wear rapidly—in fact, it wears very slowly. It causes great friction with steel, and helps greatly in the holding, and is little affected by oil or dirt.

Troubles of Cone Clutches.

To do its work perfectly the clutch must hold fast without slipping when the full pressure of the spring is applied, but must take hold gradually, slipping a great deal when the pressure of the spring is

light, and slipping less and less as the pressure is increased. This permits the gradual picking up and easy starting that is so much desired.

The faults of a clutch will of course be the opposite. It may slip when it should hold and fail to slip on first engagement, and "grab" so that the car is started with a jerk or a series of jerks. A clutch that grabs is said to be a "fierce" clutch.



CUT-AWAY SECTION OF A PLATE CLUTCH
This is similar to the disk clutch except that it employs only three plates—two attached to the fly-wheel and one connected with the shaft leading to the gearset. The plates are normally held together by means of a coil spring, shown in section.

A clutch may slip because the spring pressure is too light, because there is oil on the friction surfaces or because the leather or fabric facing is worn or has been made so hot from excessive wear and slipping that it glazes or chars and will not hold. Cone clutches as a rule are run without oil.

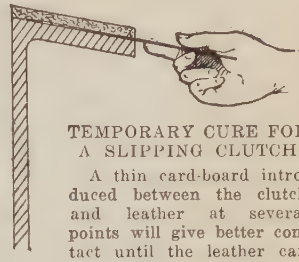
Grabbing is due to a defective condition of the friction surfaces. Commonly it is due to a hardened condition of the facing, which results in a loss of the slight resiliency which provides a little give when the clutch is let in. If the lining is of leather and is not used up from long service, it can be restored by the application of neatsfoot oil or castor oil. The oil should be allowed to soak into the leather to soften it, but no surplus should be used, as this would cause slipping. Kerosene is often used, and is fairly satisfactory.

It is not necessary, however, to remove the clutch to apply oil, unless it is in very bad condition. Simply hold the clutch out of engagement and apply the oil in any convenient way—with a squirt-can, for instance—turning the clutch to get oil all over it. Do not get too much oil on, or there will be slipping until the surplus oil is worked out. Keep the clutch out until the oil has had a chance to soak in.

If a cone clutch slips badly on the road and it is necessary to do something to enable the car to get home, pry up the clutch facing at four or five equidistant points around the circumference and insert strips of cardboard—pieces of a business card, for instance—an inch

or an inch and a quarter long. These will raise the leather and cause it to make better contact. This of course is an emergency measure. It will wear the facing in spots and should be used only when it is intended to put on a new facing at the earliest opportunity.

Cleaning a clutch facing and applying oil, as described, will cure slipping as well as grabbing, provided the spring is not too weak. If the spring is weak it can usually be adjusted. The means for adjustment vary, but in all cases the instruction book will make the matter clear.

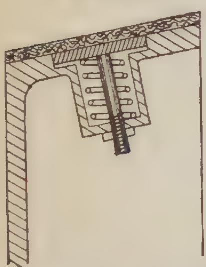


TEMPORARY CURE FOR A SLIPPING CLUTCH

A thin card-board introduced between the clutch and leather at several points will give better contact until the leather can be renewed.

Another way to free a clutch facing of oil or dirt is to wash it with gasoline. Have some one work the clutch pedal while you squirt gasoline on the facing, using plenty of it. This will carry off both oil and dirt. Then let the gasoline dry out and treat the facing with neatsfoot or castor oil.

If a clutch facing has become coated with lubricating oil first find out where the oil comes from and stop the fouling. Then, with the clutch held out of engagement, sprinkle fuller's earth or borax on the leather, using a piece of stiff paper or the like as a sprinkler. Do not use too much. The powder will absorb the oil and improve the working of the clutch. Rosin is not a good thing to use, largely because it is liable to melt under the heat of friction and make the clutch slip worse than ever. Never use lubricating oil on a clutch facing.



A SPRING UNDER THE CLUTCH FACING

This gives a smooth and gradual contact of the friction surfaces.

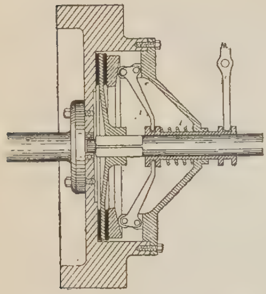
In many clutches there are springs under the leather to push it slightly outward in places. These high spots engage first and have only a light hold, so that the clutch goes into engagement very gently. In time these springs may weaken. Sometimes they can be stiffened up. If the springs are of the plunger type there will be washers to prevent the plungers from projecting too far. The removal of a washer will permit the leather to be raised sufficiently. If flat springs are used they may or may not have adjusting means. If there is an adjustment, use it; if not the spring itself can be bent to give a little more pressure.

Troubles of Disc Clutches.

When a disc clutch slips the cause is usually that the spring is too weak or that the oil—in types in which oil is used—is too thin. A mixture or half oil and half kerosene is often used, but your instruction book will tell what your clutch needs.

Harsh engagement may be due to the use of the wrong oil, to dirt between the plates, to gummed or burned oil, or to roughened plates. The plates must be perfectly smooth or they will not engage smoothly.

Too heavy an oil, gummed oil, dirt and sometimes roughened plates will prevent the proper release of the clutch when the pedal is depressed and the clutch will "spin." The driving plates usually slide on a key on the shaft. If the key gets rough or dented so that the plates cannot slide easily they are likely to stick and spin. Sometimes the edges of the plates next to the shaft and key will become marred, with the same result.



SECTION OF A PLATE CLUTCH

The friction surfaces should be smooth and kept free from gummed or burned oil.

Suggestions on the Use of the Clutch.

While the clutch is intended to slip when first let in, it should not be slipped any more than is necessary. Excessive slipping will spoil a clutch in a short time. Let the pedal come back as quickly as is consistent with smooth starting, and when the clutch is in let it stay in. Keep your foot away from it. Many drivers form the habit of "riding the clutch"—keeping the foot on the pedal all the time and unconsciously giving it a little pressure, which causes constant slipping—and constant trouble in clutch condition.

The clutch operating mechanism should always be kept well lubricated by whatever means are provided for the purpose. Requirements vary greatly in this respect, and the instruction book must be consulted.

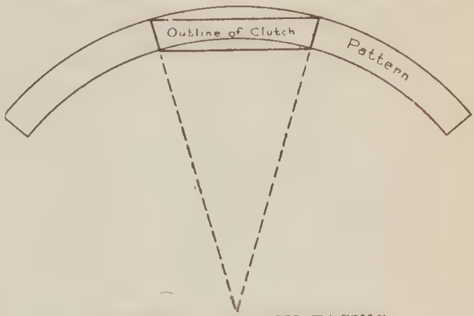
Renewing Clutch Facings.

When a clutch facing is worn out a new one can usually be obtained from the manufacturer ready to apply, and it should be riveted with the same kind of rivets used in the old facing. The work must be carefully done, and it is very necessary to make sure that the rivet heads are countersunk well below the leather surface.

If it is impracticable or impossible to get a new leather cut to shape, one can be cut from a pattern. If the old facing can be removed intact, or nearly so, it can be used for the pattern.

Draw the outline of the clutch on a large piece of heavy paper, making it the exact size of the actual clutch and taking great care to have the angle of the cone precisely right. Draw a long line through the center. Now continue the lines of the cone until they meet in a point on the hub line and use this point as a center from which to strike the lines of the pattern, which must pass through the corners of the clutch as you have

drawn it. The length of the long side of the pattern must of course be equal to the circumference of the clutch cone where it is greatest, and for the sake of safety it is better to make it a little longer to allow for cutting where the ends butt together. Cut out this pattern carefully and use it to cut the leather.



CUTTING A CLUTCH FACING

The new leather should be absolutely smooth when applied and consequently it should be cut of exactly the right size and curvature.

The leather is heavy, sometimes quarter of an inch thick. Soak it with neatsfoot or castor oil to make it as pliable as possible before riveting it on. It is important that the new leather should be of the same thickness as the original when new.

Rivet one end of the leather in place. Then stretch it as tightly as possible and put in the next pair of rivets, using a small clamp to hold it while riveting, and so on all the way round. In this way the facing will be tight all over, which is important. If you try to rivet the ends first and then put in the intermediate rivets you are almost sure to have the leather bulging in some places.

Use a good grade of belting leather.

If a lathe is available true the facing by taking a light cut over it. If no lathe is available, try the cone in its place, moving it to mark the high spots, and rub them down with sandpaper or a coarse file until a good bearing is obtained all round.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER I, SECTION III

Why a car needs a clutch.

What types of clutches are used.

What a cone clutch is.

What a reversed cone clutch is.

What a disc clutch is.

What a plate clutch is.

What makes a clutch hold.

What troubles a cone clutch is subject to.

How to cure cone clutch troubles.

What troubles a disc clutch is subject to.

How to cure disc clutch troubles.

How to prevent grabbing and slipping.

How to clean a clutch facing.

How to adjust clutch facing springs.

How to make a clutch hold in an emergency.

How to use the clutch.

CHAPTER II

THE GEARSET

Why the Car Needs a Gearset.

An automobile needs a gearset for the same reason that it needs a clutch—because of the engine's low power at low speed.

To illustrate the point, suppose there were no gearset, the drive being direct to the rear axle so that the car would always run on direct drive, or what would be high speed with a gearset.

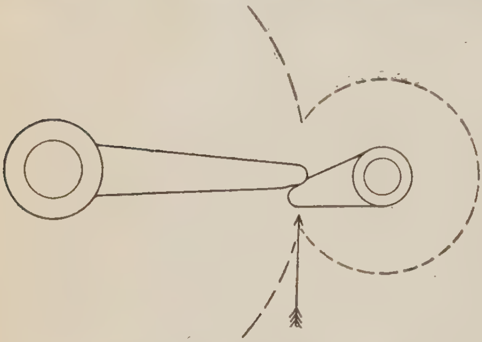
To begin with, it would be difficult to start the car, for some little power is required. It would be possible, however, under good road conditions, by speeding up the engine and letting the clutch slip excessively at first. Once started, the car would run as is usual in high gear. As a matter of fact, when running at ordinary road speed on a good road the engine is required to develop only a small part of its rated horsepower, and the engine is capable of developing only part of its power at low speed.

But a grade is encountered. The throttle is opened to give the engine more fuel, and in this way the power can be somewhat increased without an increase of speed. But when the engine is taking all the fuel it can handle at a given speed there is no way of increasing power without increasing speed and enabling the engine to burn more fuel. But the grade has been increasing, and it slows down the car and the engine, and of course the engine grows weaker as it slows down and stalls.

Now it is time to desert the direct drive. Something must be done to allow the engine to run faster and develop more power without proportionately increasing the speed of the car. And this is where the gears come in. Suppose the driving shaft is divided and the part attached to the engine is fitted with a small gear and the part attached to the rear axle with a large gear. Now the speed of the engine and the shaft with the small gear will be slower than the speed of the shaft carrying the large gear in exactly the proportion that the large gear is larger than the small one. If one gear is twice the diameter of the other the engine will run at twice the speed of the driven shaft. This is the principle of all change-speed gears. If you arrange several sets of gears so that you can bring into engagement gears of varying relative sizes you will have a gearset, and you can vary the speed of the engine

with relation to the speed of the rear axle and that of the car as much as you please within the limits of the gears.

There are two reasons why lowering the gear—that is, increasing the speed of the engine with relation to the speed of the rear axle—enables the car to do harder work. One, already referred to, is that the engine gains more power by its increased speed. The other is that the gears act as levers, and driving from a small gear to a large one is precisely the same in principle as shifting the fulcrum of a lever so that the force is applied to a longer end. In fact, gears are nothing but revolving levers. Suppose you cut away all of the gears except the teeth actually in mesh and the steel between the teeth and shafts. You now have a tooth on the engine shaft lifting at the end of a lever on the driven shaft. The longer the lever on the driven shaft the greater will be the pull, other things being equal.



GEARS ARE LEVERS

If we consider only the teeth in contact, it is easy to understand what gear reduction is.

Thus the change in leverage will enable the engine to pull harder, though at a lower speed, without itself running any faster. But it will be running faster in proportion to the speed of the car.

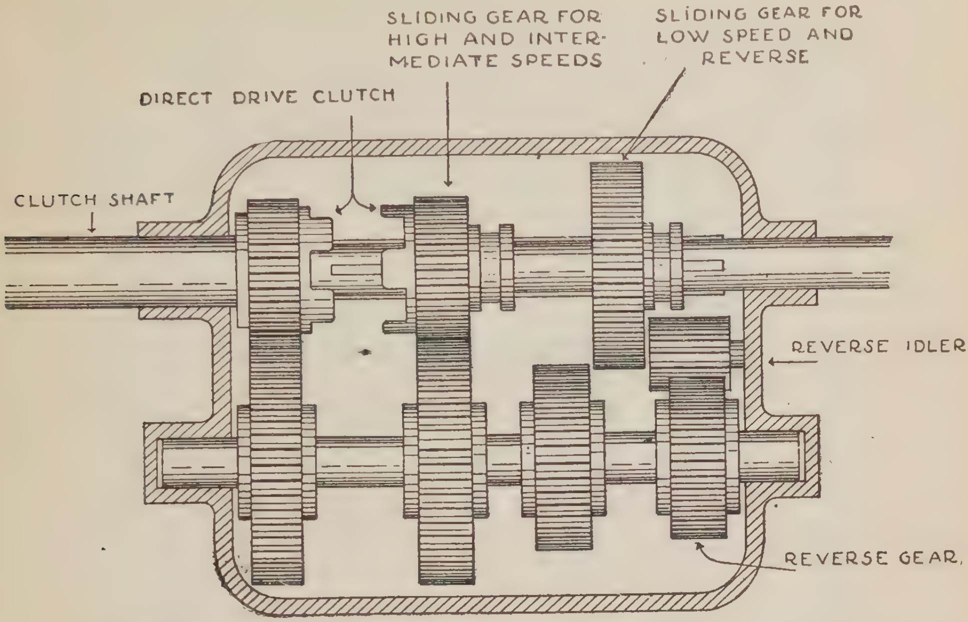
Here it is well to call attention to the fact that strictly speaking the transmission system includes all parts transmitting power from the engine to the rear wheels—clutch, gears, propeller shaft, bevel gears and rear axle. The gearset—which is the proper term, though it is very commonly called the transmission—is simply part of the transmission system.

Types of Gearsets.

The standard type of gearset is the sliding gear, selectively operated. The gears are mounted on parallel shafts so that gears of various relative sizes can slide into and out of mesh. While the sliding gears can move along their shafts they cannot turn on them because there are "splines" or longitudinal keys which fit into corresponding grooves in the hubs of the gears. Usually there are several splines cut integral with the shaft so there will be ample wearing surface and the gears will not work loose.

Selective operation means simply that any pair of gears can be meshed at will without having to throw other gears in and out of mesh first. In the old "progressive" system of gearshifting it was neces-

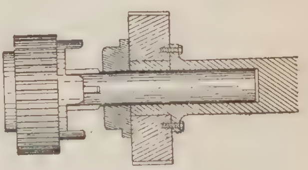
sary, for instance, in changing from high to low speed to mesh and unmesh the intermediate gears on the way. Going from high gear to reverse involved going through all the intermediate speeds.



THE INSIDE OF THE SELECTIVE SLIDING GEAR TYPE OF GEARSET

The gearset is here shown in second speed. The reverse gear on the main shaft slides over the reverse idler which is placed lower down (below the two shafts) so that the teeth can mesh properly.

There is always a "neutral" point where there is no gear connection from the engine to the propeller shaft. This is absolutely necessary because the normal position of the clutch is "in," and if no neutral position were provided the clutch would have to be held out whenever the engine ran without driving the car.



THE DIRECT DRIVE CLUTCH

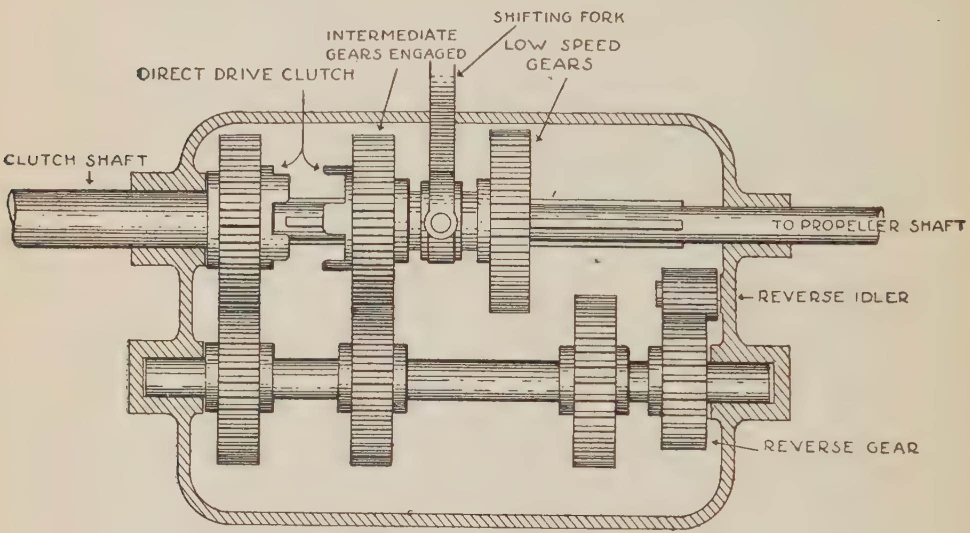
When the gear is in mesh with the jaws of the clutch, the clutch shaft and the main transmission shaft revolve as a unit when the gearset is placed in "direct," or, as it is generally known, "high" speed.

Most cars have three speeds forward and always there is one reverse; the reverse is not counted in enumerating speeds. A few cars have four speeds, and some of the lower-priced cars only two.

High speed is "direct." That is, none of the gears in the gearset are driving, though in most gearsets the countershaft revolves idly, its gear being always in mesh with the driving gear on the engine shaft. This direct drive is effected by leaving all the sliding gears out of mesh and clutching the primary shaft to the engine shaft by means of some form of jaw or tooth clutch. This is sometimes simply a small gear which

slides into a recess of exactly its own shape—an internal gear, in fact. Sometimes it is a serrated clutch, with sections cut out into which corresponding projections in the other half fit. The action is the same in any case.

Reverse is obtained by interposing an idler gear between two of the



THE PROGRESSIVE TYPE OF SLIDING GEAR

In the ordinary gear of this type, high or direct speed can only be reached from neutral by passing through the first and second in succession. In one type, however, the reverse is obtained by a sideways thrust of the lever. Low is toward the rear and the neutral and second toward the front; consequently, only the intermediate gear must be passed through in order to reach the neutral from high.

driving gears. The usual arrangement is to have the idler between the low-speed sliding gear and a special gear on the primary shaft. The interposition of an idler does not change the gear ratios; the ratio is precisely the same as if the two principal gears were meshed. It does, however, reverse the direction of rotation.

What the Planetary Gear Is.

Planetary gearing is usually considered complex and hard to understand. It is not. The principle is really simple, and the accompanying diagrams make it clear. The Ford gearset is of the planetary type. The term planetary is used because the movements of the gears resemble the movement of the sun and planets. In fact, early gearing of this sort, used long before automobiles were built, was called "sun-and-planet" gearing.

Referring to the diagram, A is an internal gear, which is simply a ring with teeth cut on the inside instead of the outside. BBB are inter-

mediate pinions and C is a gear on the engine shaft. The intermediate pinions turn on studs set in a disc.

For the purpose of illustration, we will assume that the engine shaft ends at the gear C while the propeller shaft is attached to the center of the disc carrying the pinions BBB. If the large internal gear A is held so that it cannot turn, and the engine shaft and its gear C are rotated the intermediate pinions BBB will of course be driven and will turn on their studs in the disc. But as these pinions also mesh

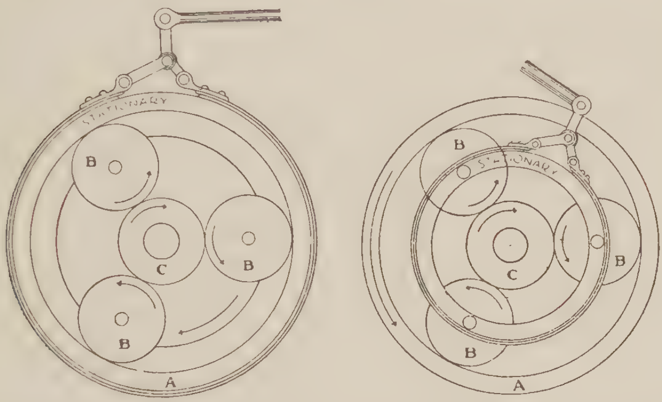


DIAGRAM OF THE PLANETARY LOW SPEED AND REVERSE

In this type the gears are always in mesh, the speed being obtained by means of the friction brake-bands. Such systems are, as a rule, limited to two forward speeds and one reverse.

with the internal gear, which cannot turn, they are forced to run around in the space between A and C, and the disc on which they are mounted will perforce turn with them, turning the propeller shaft. This will give a low speed because of, and in proportion to, the difference in the sizes of the gears A and C.

Now suppose the members are arranged a little differently. The engine shaft carries the center gear C in the same way; but the disc to which the propeller shaft is attached is attached to the internal gear A instead of to the pinions. The pinions run on studs on a disc as before, but the disc is arranged so that it can be held stationary, not turning as in the previous case. The pinions can revolve only on their own studs; the pinion disc being stationary, they cannot run around between the shaft gear and the internal gear. Now follow the movements. The shaft gear turns, causing the pinions to rotate on their studs and to drive the internal gear which is attached to the propeller shaft. Now, however, the propeller shaft will be given a reverse direction because the disc is stationary, and we have a low reverse speed.

For the high speed the gears do no work. They are all clutched

together and the whole assembly rotates with the shaft, so that the effect is precisely the same as if a solid shaft were used. This is one of the advantages of the planetary system.

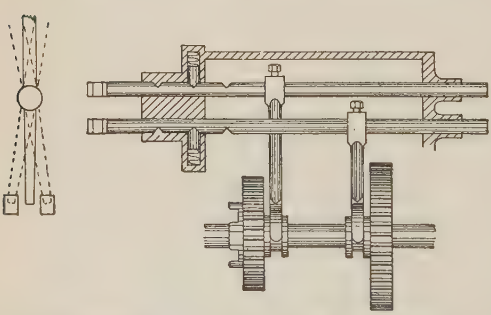
It is necessary to use two separate sets of gears, one for low speed and the other for the reverse. From a practical point of view the planetary gear is limited to two speeds. Three speeds can be obtained, but the disadvantages greatly outweigh the advantages.

Gearset Lubrication.

The gears of a gearset are among the most carefully made parts of the car. Tremendous strength and great resistance to wear are required and provided by the use of very high-grade steels accurately finished and made very hard. Gear trouble once was common. Now it is rare. With adequate lubrication and reasonably careful use the gearset will give no trouble to speak of.

The matter of lubrication is all-important, regardless of the type of gearset. The pressures on the gear teeth are very heavy, and if too light a lubricant is used it will be squeezed out and the metal surfaces will come together and wear. If it is too heavy it will not work around as freely as it should and, moreover, it will absorb a surprising amount of power in merely moving the gears through the heavy mass. The lubricants used differ quite widely, but as a rule a heavy oil or a light grease is used. A heavy grease would not work into ball bearings. Too light an oil, on the other hand, would not only fail to lubricate the gears effectively, but would work out through the bearings.

Stick to the lubricant specified by the maker, and, as in other parts of the car, avoid cheap lubricants. There is absolutely no saving in their use. They will not last as long as good stuff and they permit more wear, so that it is a case of saving pennies at the cost of dollars—"Penny wise and pound foolish."



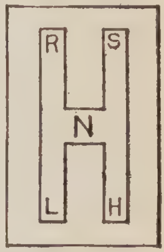
THE SELECTOR RODS OF THE SELECTIVE SLIDING GEAR SYSTEM

The notches in the rods are to hold the proper gear in position until released by the shifting handle. The springs holding the pin in place should be strong enough to prevent any of the gears from jumping out of mesh.

Types of Gearshifts.

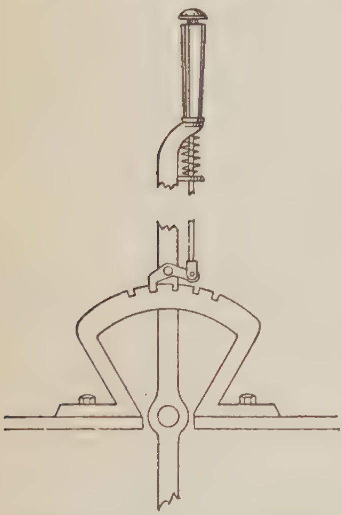
Sliding gears are moved by means of forks which engage in grooves cut in the hubs of the gears to be moved; the drawing makes this clear. The forks are attached to sliding rods which are moved by the gear-shift lever. Moving the gear-shift lever sideways

causes it to engage with different rods, while moving it forward or backward, after the rod has been engaged, causes the gears to slide. In the center neutral position is obtained. The sliding rods are fitted with detents or catches to hold them in the positions taken when the gears mesh. Usually the detents are steel plungers which drop into notches in the rods and are held by springs. The plungers and notches are so shaped, however, that when pressure is applied to the rod the plunger will be forced up and out.



THE "H"-PLATE
This is frequently used to illustrate the speed positions of the shifting lever.

In many cases the gearshift lever is guided by an "H-plate," which is simply a steel plate with slots cut in it to ensure movement in the right direction and to properly limit it. The slots run together and form an H. When the lever is in the cross-slot of the H the forks are between the sliding rods, engaging neither of them. The gearshift lever cannot be moved into the center of the H without moving the sliding gears out of engagement. It will be clear that from the neutral position any gear can be engaged at once by first shifting to right or left and then forward or backward, according to the desired gear.


POSITIONS OF THE PROGRESSIVE SHIFTING LEVER
The first notch is reverse; the second, neutral; the third, low; the fourth, intermediate; the fifth, high.

The usual system of movements for changing gears is as follows: Central position, neutral; to the left and backward, low speed; straight forward all the way from low, reverse; to the right from neutral and forward, second or intermediate speed; all the way back from second, high speed.

A popular form of gearshift lever is the "cane" type which works in a ball-and-socket joint. In this case the lever is moved into the various positions in the same way and the positions are the same.

In the old progressive type of control there is a notched sector over which the lever moves, the reverse position being at one end of the sector and high speed at the opposite end and other positions between in progressive order. There is only a backward and forward movement.

Gearset Troubles.

As has been stated, gearsets are usually well made and not likely to

give serious trouble. Sometimes the shifting of gears becomes more or less difficult because of the burring of the teeth through bad handling or wear of the lever at the point where it engages the sliding rods. If the various parts are not properly lubricated they may bind. If the gearshaft bearings are worn much it is likely to cause the gears to go together hard.

If it is found impossible to engage the gears without clashing and grating see that the clutch is not dragging so that the gears are kept spinning when they should stop.

Gears that run noisily because of worn teeth may be somewhat quieted by the use of a heavier lubricant. Care must be taken, however, not to use too heavy a grease, and the service station may well be consulted in the matter.

Worn bearings are detrimental to the whole gearset, causing the gears to wear out of shape and with abnormal rapidity. The replacement of the bearings is a repairman's job, for it must be done right. Gear teeth may be smoothed—by the repairman—and he can correct trouble between the lever and the sliding rods. Occasionally the detents on the sliding rods slip out too easily, in which case the trouble can usually be cured by increasing the pressure of the spring or, if the notch is worn, deepening it slightly.

In planetary gearing the clutch bands wear and slip after having been used for some time. These are readily adjusted. See that the bands on the low speed and reverse drums are not too tight. If they are they will drag when they should be free and cause friction and unnecessary wear, as well as absorbing and wasting power.

The gears get noisy when worn, and they will be noisy if not properly lubricated, even though they may not be worn.

Occasionally shifter forks are bent, through rough handling, so that the gears are not fully meshed when the shifting lever is in proper position. This reduces the contact area of the gear teeth and causes rapid wear and noisy operation. In some gearsets the high-speed clutch teeth wear at an angle, so that there is a tendency to push the clutch out of engagement when power is applied. If the angle is great enough the clutch will sometimes be pushed out against the restraint of the detent on the sliding rod. In either case have the repairman do the job, and have it done as soon as possible.

Suggestions on Gearshifting.

The quiet shifting of gears is by no means a difficult matter, and it is all the easier if one understands the matter.

Just before changing gears the clutch is pushed out. This discon-

nects the engine from the shaft on which the sliding gears are carried and leaves the shaft free. It will continue to turn, however, by its own inertia for a moment after disconnection. The other shaft is still moving because it is connected with the propeller shaft and must turn as long as the car is moving. The point is to shift while the splined shaft is still spinning, so that it will slip easily into mesh with the new gear and will change its own speed to faster or slower, according to the shift, without shock. If the change is delayed until the splined shaft stops you will have to mesh a gear that is not turning with one that is turning quite rapidly, and the result will be a clashing and grating of gear teeth—which is very hard on the ends of the teeth—and perhaps difficulty in getting the gears to go together. So make the change only an instant after throwing out the clutch. Practice will indicate how long—or rather, how short—an interval should elapse. This may vary with the gear—whether first, second or third—but not appreciably with the speed of the car.

Shifting with the car standing is a different matter, for with the clutch out all the gears are idle and there is nothing to prevent their engagement—unless it should happen that the ends of the teeth come squarely together. This possibility is minimized by the rounding of the ends of the teeth. If the gears will not go into mesh do not under any circumstances try to force them, or you may bend the forks or some part of the shifting mechanism. Just let the clutch part way in for a touch, and this will move the gears.

The movement of the gear lever should be quick and decisive. The thing is to get the gears in and out with as little delay as possible on the way. And the throwing out of the clutch should also be done without delaying or dragging. Watch a good driver, and you will see that he does not lag in his gear-shifting movements. He does the job in a jiffy—with the proverbial neatness and despatch.

Shifting to a Lower Gear.

Some cars will shift more easily to second speed from high than will others at the same rate of car travel. In other words, cars will vary in the speed at which they can be most easily changed to the lower gear ratio. When the gearset is shifted to a higher speed, the engine turns more slowly for the same rate of car travel; when shifting to a lower gear, the reverse is true and the engine must turn over faster. If it is desired to shift to a lower gear from a higher speed than that at which such a change can be made smoothly, the following "double shift" is recommended and will be found satisfactory, after considerable practice.

The Double Shift.

First, let the foot off of the accelerator, throw out the clutch, and shift into neutral—instead of moving all the way through to second. Immediately release the clutch and give the accelerator a slight tap with the foot to speed up the engine, then push out the clutch and move the shifting lever on into second speed. The reunion of the two parts of the clutch at the same time that the engine is accelerating and the transmission is in neutral, will serve to bring the gears which are to be meshed, to approximately the same speed of revolution. Do not practice this when going up a steep hill, for the fraction of a second of additional time required will cause a car to loose speed.

The average modern car has such ample power that high gear can be used perhaps 90 per cent of the time, on an average. But there is such a thing as carrying the high gear idea too far. There is nothing gained by sticking to high on a hill up to the last possible moment and shifting down just in time to save the engine from stalling. When the engine runs slowly pulling up a grade you can feel the separate impulses in the cylinders, especially in a four-cylinder engine, and this causes unnecessary wear on the engine and is hard on the clutch and, in fact, on the whole of the transmission system. The engine will do its work much more easily and smoothly on a gear that enables it to pull easily and with something to spare. On the other hand, too low a gear allows the engine to race and is also undesirable. Use always the highest gear on which the engine will pull easily and smoothly.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER II, SECTION III

Why a car needs a gearset.

Why a lower gear gives more power.

How gears resemble levers.

What the transmission system is.

What types of gearsets are in use.

How the sliding gear works.

How the planetary gear works.

What selective operation is.

What progressive operation is.

How direct drive is obtained.

How reverse is obtained.

Why proper lubrication of the gearset is vital.

How gears are controlled.

What the H-plate, or gate, is.

Why the selective control is better than the progressive.

What troubles gearsets develop.

How to avoid gear troubles.

Why the high speed sometimes slips out.

What troubles planetary gears develop.

How to shift gears.

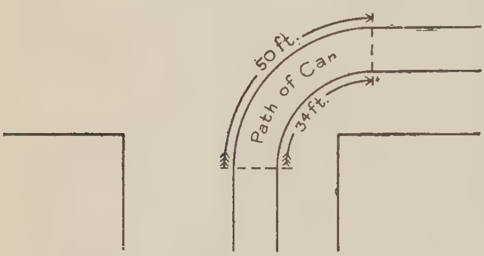
When not to use high gear.

CHAPTER III

THE FRONT AND REAR AXLES

Why a Car Needs a Differential.

When a car is running straight both rear wheels run at exactly the same speed. On a turn, however, the outer wheel runs faster than the inner wheel because it has a greater distance to travel and must do it in the same time that the inner wheel occupies in making the shorter distance. So the differential gear is used, and this not only permits one wheel to travel faster than the other, but permits both being driven, despite the difference in speed.



WHY A CAR NEEDS A DIFFERENTIAL

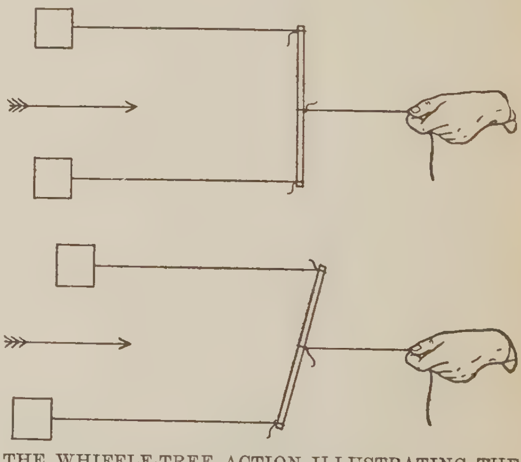
When rounding a corner the inside wheel has less space to cover than the outside wheel. The differential takes care of this.

The rear axle is made in two parts, the division being at the center, and the differential gear connects the two parts.

How the Differential Works.

The action of the differential is not difficult to understand, if the underlying principles are grasped.

Suppose you take a stick, tie a string to each end, fasten two weights, precisely alike, one to each string, and then tie a third string, exactly in the center of the stick and by the third string draw the weights along the top of a smooth table. There will be an equal pull on both ends of the stick and it will keep straight as you pull.

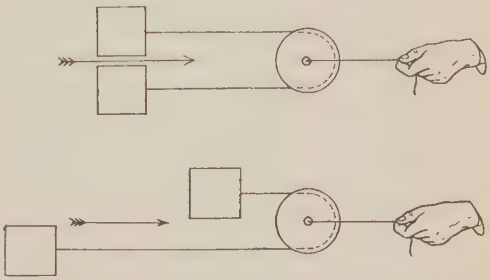


THE WHIFFLE-TREE ACTION ILLUSTRATING THE DIFFERENTIAL PRINCIPLE

As one weight is held back the other moves forward faster.

Suppose, however, you hold back one

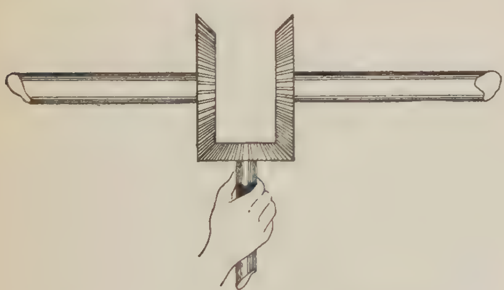
of the weights a little. One side of the stick gets a heavier pull than the other and that side will lag and let one weight move faster than the other. This is "differential action." But the movement of the stick is limited, and when its limit is reached the differential action ceases. So instead of a stick use a wheel with a grooved rim and run the string around it, with the same weights on the ends. Now you can draw the weights as before, but the differential action can be continued as far as the length of the string will permit. You can draw along the weights and change their speed with relation to each other, but you will always be applying power to both.



ANOTHER ILLUSTRATION OF THE DIFFERENTIAL PRINCIPLE

The cord passes around a pulley. If one weight is slowed down the other moves correspondingly faster.

Now let us apply the principle to an axle. Suppose you have an axle divided in the middle and a bevel gear on each of the adjacent ends. Take a small bevel gear—it is called a bevel pinion—mounted loosely on a stud. Place the pinion so that it meshes with both the axle gears. Hold the pinion by the stud, so it can turn freely, and move it in a circle, following the circles of the gears. The pinion will make both halves of the axle turn at the same speed because, as in the case of the stick, the pull is applied to the center and the resistance at the circumference — corresponding with the ends of the stick—is the same on both sides. Apply a little friction to one of the axle shafts, however, and an extra resistance will be added to one side of the pinion, and this will cause it to turn on its stud while it is being swung around the circle, allowing one shaft to move faster than the other.

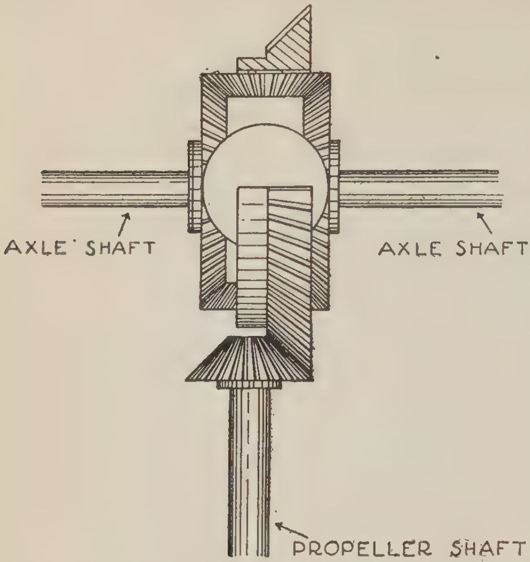


APPLYING THE DIFFERENTIAL PRINCIPLE TO A GEAR

The two ends of the shafts are connected to the wheels. When the hand grasps the pinion shaft tightly so that it cannot turn and sweeps around in a circle, we have a condition corresponding to the straight-ahead drive of a car in which the differential is not brought into action.

This is the principle, and in fact the greater part of the mechanism of the differential. All you have to do to complete the gear is to use three or four pinions instead of one—to give greater wearing surface and steadiness—and, instead of holding the pinion studs in your hand, mount them on a ring which is so supported that it turns as the gears

turn. On this ring place another bevel gear and drive it from a bevel pinion on the end of the propeller shaft. There you have the complete differential in its ordinary form.



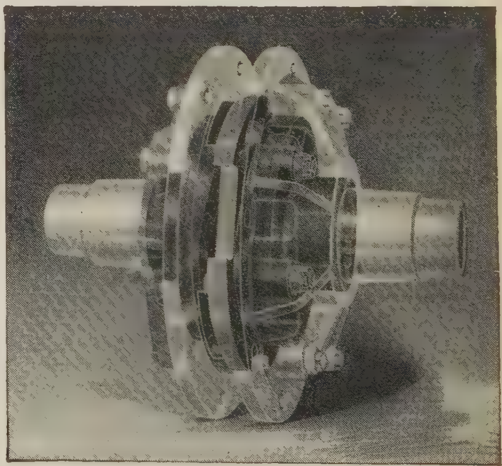
BUILDING UP A DIFFERENTIAL

Substituting the engine propeller shaft for the main shaft and the large master gear as the basis for support of several bevel gears as shown in the preceding cut, we have a complete differential as used on the majority of automobiles.

Differential gears have been made using spur gears—that is, gears with teeth cut straight across instead of at an angle. The principle of operation is precisely the same, though the spur gear arrangement is a little more complex. But the bevel gear type is in use in the very great majority of cases.

Other Types.

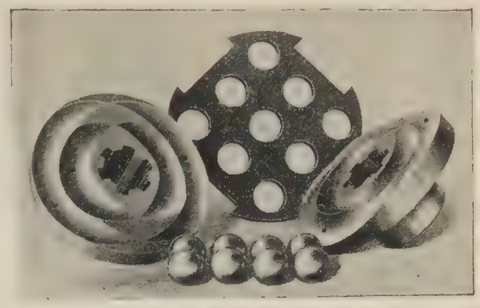
The ordinary differential, whether of the bevel or the spur type, has a serious drawback. If one wheel is held so that it can turn only when considerable force is applied, and the other is left free, the latter will be driven while the former will remain stationary. Because of the action of the gears the moving wheel will revolve twice as fast as if both wheels were turning in the ordinary way. So if, when driving, one wheel strikes a slippery spot, such as a sheet of ice, while the other has a good hold on the ground, the latter will, under certain conditions, stop turning and the wheel on the slippery spot will spin—as everyone who has driven a car knows very well. This is precisely opposite to the effect that is wanted. A number of differentials have been invented to overcome this trouble, some using worm gearing, some spiral gears and others various forms



PHANTOM VIEW OF A SPECIAL DIFFERENTIAL

In this device the power is applied to the wheel having the most traction instead of to the wheel that slips easily, as is the case with the ordinary type of differential.

of friction and other locks. All have the same end in view—the prevention of spinning when one wheel loses traction—and both wheels are driven even when one has no grip on the ground. Some of these inventions have worked out well and are coming into wider use.



THE PARTS OF THE SPECIAL DIFFERENTIAL

The balls move in such a manner that the greatest friction, and consequent driving force, is transmitted to the wheel which offers the greatest resistance to turning.

Often the ring carrying the pinions is extended to form a housing around the differential gears, so that only the driving bevel, which meshes with the propeller shaft pinion, is outside. The whole mechanism, in turn, is always enclosed in an enlarged part of the rear axle housing. The forward part of this housing supports the bearings for the propeller shaft bevel pinion.

Troubles of the Differential.

Differential troubles are confined mainly to wear, which causes the gears to "growl" when a turn is made. With good lubrication the differential wears a long time. It is suggested that if adjustment is required the repairman be allowed to do it. As a rule it is a job that is somewhat delicate, and if not properly done the gears will wear rapidly.

In some cars no provision is made for adjustment. The gearing is very carefully and well-made and, as the normal wear is slight, it is considered that it is better to keep the assembly as simple as possible and if the parts become worn, to replace them with new ones. Some of the highest grade cars have non-adjustable differentials.

A worn differential should not be allowed to run any longer than is necessary, for when the gears are not meshing properly they are more easily broken than when they are properly meshed; and a broken differential gear is a very unpleasant thing indeed.

No Differentials.

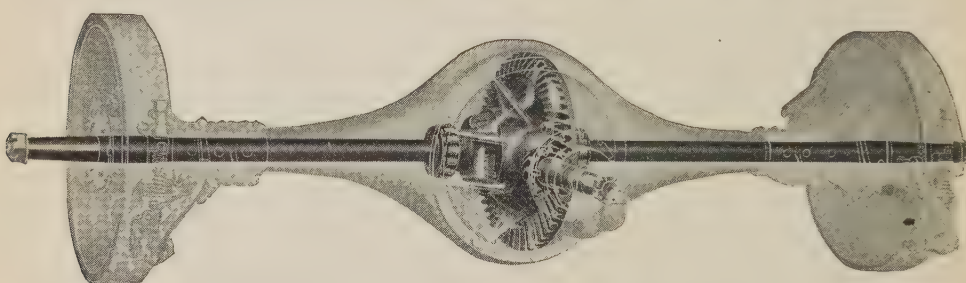
In many racing cars no differential is used, the wheels being allowed to slip on the turns. The saving in weight and the greater strength and simplicity are considered of greater advantage than the saving on the tires. Low-priced light cars with narrow treads also are often made without differentials. The distance between the wheels being short, there is less difference in the relative speeds of the inner and

outer wheels in making turns than when the tread is wider, and the light weight also is a factor.

Types of Rear Axles.

In a general way all rear axles are alike. That is, there is always a divided axle with the differential and bevel gear drive and the differential at the center and a housing which encloses all the parts and gives a solid support for the bearings carrying the shafts. There are differences in details, however, and chief among these is the method of connecting the shafts to the road wheels. According to the construction of this part of the axle, it may be a semi-floating, a three-quarter floating or a full-floating axle.

In the semi-floating axle the live shaft is carried straight out through



PHANTOM VIEW OF A SEMI-FLOATING REAR AXLE
The wheels must be removed from the axle by means of a wheel puller. The live axles are mounted on the inside and outside bearings and the wheels are supported on the projecting ends.

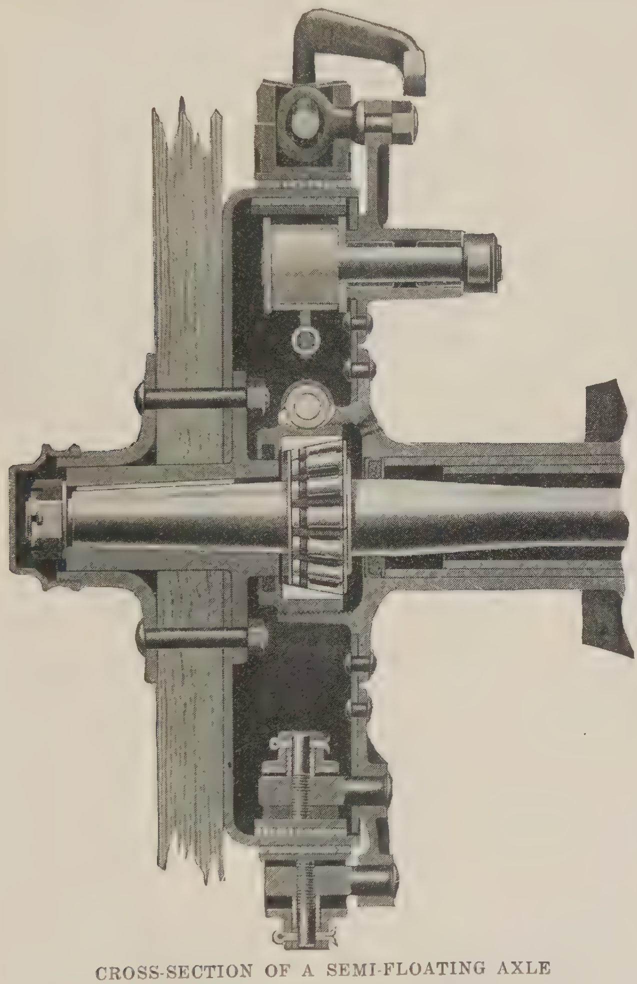
the hub of the road wheel, to which it is keyed fast, so that the wheel and axle form a unit. The inner end of the shaft is usually held in place in its differential gear by a nut, so that to remove it the nut must be loosened, after which the wheel and axle can be withdrawn together.

In the three quarter floating axle the road wheel is mounted on the end of the axle housing, and thus the shaft does not have to carry any of the weight of the car. The end of the shaft is keyed to the hub of the wheel to give the drive.

In the full-floating axle the wheel is mounted, as in the three quarter floating type, on the housing. Instead of the shaft being keyed to the hub, however, it is made with a flange or spider which has teeth interlocking with teeth in the hub of the wheel. The inner end of the shaft is squared or splined into the hub of the differential gear. With this construction the axle shaft can be slipped out without the trouble of getting into the differential housing to loosen a nut and without removing the wheel from its place on the housing.

In the semi-floating and the three quarter floating types the shaft has a bearing in the end of the housing. In the full-floating type the shaft

usually has no end bearing. There is a sort of intermediate type of axle sometimes called "seven-eighths floating." This axle carries the wheel on the housing and the end of the shaft runs in a bearing. Instead of being keyed to the wheel hub, however, the shaft carries a flange which is bolted to the wheel, and the removal of the nuts permits



CROSS-SECTION OF A SEMI-FLOATING AXLE

The axle carries the projecting end of the shaft on which the bearing is mounted. The axle can only be withdrawn by loosening the nut of the differential.

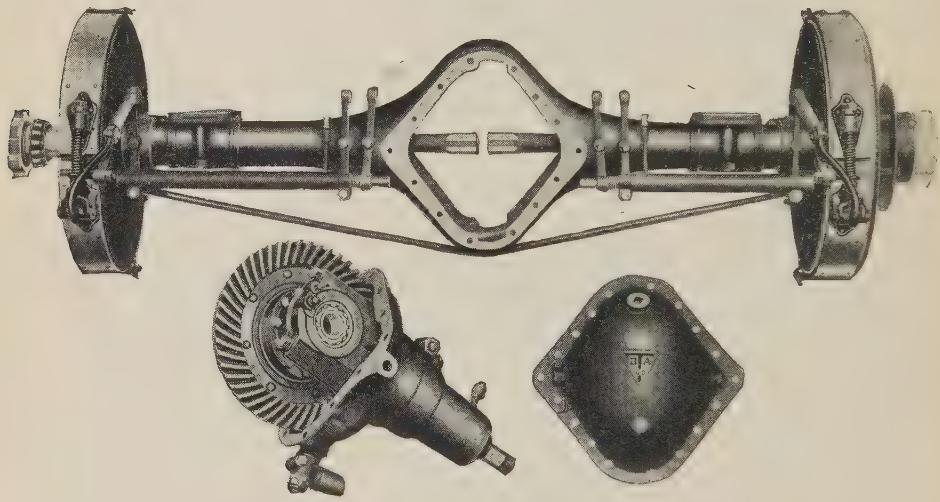
the shaft to be removed without moving the wheel. The inner end of the shaft floats in the differential, as in the case of the full-floating type.

Constructional details differ considerably in different axles, and it will help matters to study the drawing of your axle in the instruction book and become familiar with its design.

Rear Axle Troubles.

Rear axle troubles are mainly in bearing wear and wear of the clutches that connect the live shafts with the wheels. In most cases worn bearings must be replaced, though some are adjustable. Roller or ball bearings are always used, and sometimes both types are found in the same axle.

In a full-floating axle the driving clutches or dogs sometimes wear considerably. When such wear occurs there is a shock and a blow every time the drive is taken up, and this greatly accelerates further wear.



A FULL-FLOATING AXLE AND DIFFERENTIAL DISSEMBLED

Either half of a live axle may be pulled out from the housing by loosening half a dozen nuts or by removing the hub cap. The wheel is mounted on its own bearings, carried on the end of the differential housing, instead of on the projecting end of the live axle.

Sometimes wear can be taken up by having the clutch teeth hammered out and then filing them to fit. In other cases new dogs will be required.

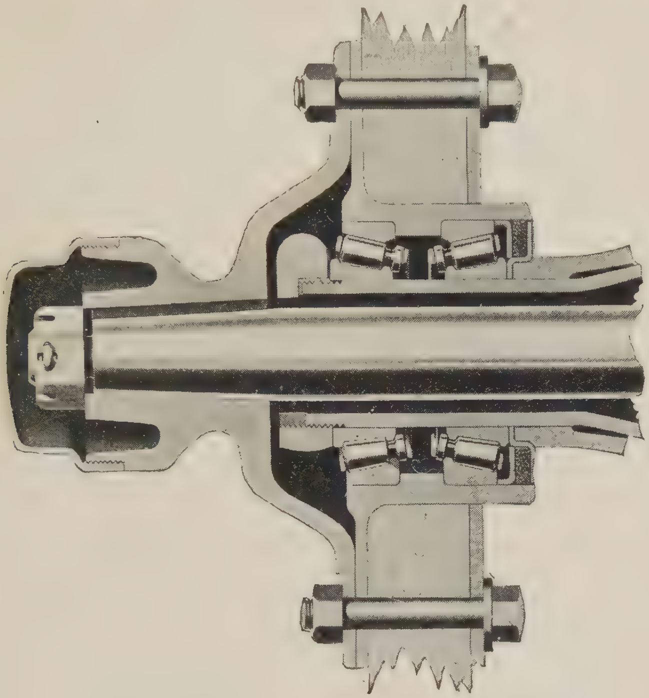
Taking a semi-floating axle apart to replace bearings involves jacking up the axle to take the weight off the wheels. Then remove the hub caps. There will be found a nut on the end of the live shaft, which must be removed. Then the nut on the differential end of the shaft must be removed. The wheel and shaft can be pulled out, and the wheel removed from the shaft, should this be necessary, with a wheel puller.

Don't attempt to knock the shaft out of the wheel with a hammer if it is very tight. It is very poor policy and may do a good deal of damage.

Use of Wheel Puller.

A wheel puller is not part of the regular equipment of a car, but it is an exceedingly useful appliance. Various types are made, and any-

one who does much work on his own car ought to have one. The smaller sizes, or the larger sizes adjusted, can be used for removing gears such as the timing gears. For simply removing wheels there are pullers of the hub-cap type. This tool simply is a cap which screws on



CROSS SECTION OF A FULL-FLOATING AXLE

By removing half a dozen or so bolts and unscrewing the flange and cap to the wheel, the entire half of the live axle may be removed, leaving the wheel still in place on its bearings—which are carried on the ends of the axle housing.

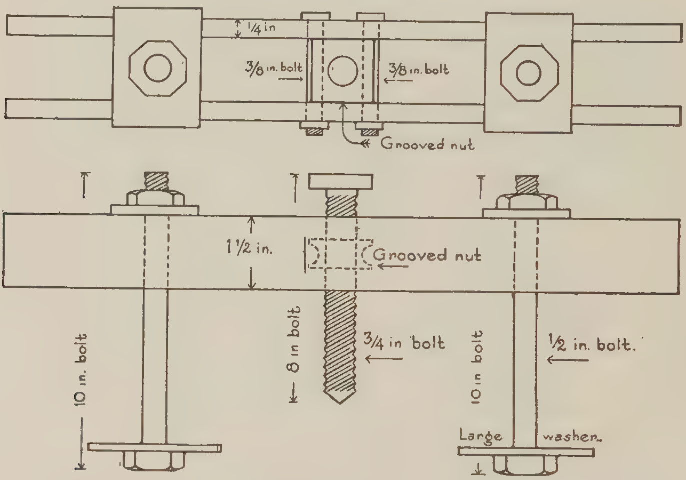
in place of the hub-cap and has a central screw which, when tightened, presses against the center of the live shaft and forces the wheel off.

Improvised Wheel Pullers.

A wheel can readily be removed with the aid of a jack and a piece of rope. The jack, preferably a small one, is placed with its head against the end of the shaft after the hub-cap has been removed and the nut unscrewed from the shaft end. Pass the rope around the wheel spokes near the hub and over the base of the jack. It will be necessary to carry the rope over at least three spokes so that the jack will be supported when pressure is put on.

Screw up on the jack, and when there is a good pressure give the jack a blow or two with a hammer. If the wheel does not come, tighten up a little more and use the hammer again.

A regular puller can be made from cheap and easily obtained materials. Get a ¾-inch bolt about eight inches long with a square nut, and two pieces of cold-rolled steel about ten inches long, an inch and a half wide and quarter of an inch thick. With hacksaw and file cut two grooves on opposite sides of the nut making the grooves as deep as possible without going through to the threads, and large enough so that three-eighths bolts will go into them snugly. Drill the steel bars for the three-eighths bolts and bolt them together with the nut between, the bolts passing through the holes in the bar and the grooves in the nut. File the end of the big bolt to a rather obtuse point. The point is placed in the center of the shaft from which the wheel is to be pulled.



A HOME-MADE WHEEL PULLER

Wheels are keyed solidly to their shafts or axles and considerable pressure is required to remove them. The wheel puller described in the accompanying text will do as good work as a much higher-priced one especially made for only one type of car.

For arms you can use bolts of any length that the job may require. To pull a wheel, use side bolts or arms long enough to reach back of the spokes and run them through iron plates resting on the backs of the spokes. For smaller work smaller arm bolts can be used, and instead of plates, washers. Oil the big bolt so that it will work easily through the nut. Of course such a puller can be made in any size required, and it is a useful and practical tool.

Removing a Flywheel.

The removal of a flywheel keyed to the crankshaft is not a job that has to be done often, and it is not worth while to have a special puller for the job, for a big one is necessary. The following method has been used with success:

Get a piece of hard wood about four inches square and six or eight inches longer than the diameter of the flywheel. Bore a one-inch hole through the middle and through the hole pass a one-inch bolt with the end filed to an obtuse point. Get a washer big enough for the bolt to pass through, slit it with a hacksaw and bend it so there will be two ears or lugs sticking up so that the square nut will rest between them. Bend down two other lugs in the opposite direction. Put the washer in place in the wood bar and tighten on the bolt till the lugs of the washer are forced into the wood. This is to keep the nut from turning when the bolt is screwed in. Lay the bar across the face of the flywheel with the point of the bolt in the recess in the center of the shaft. Pass a chain or a stranded wire clothes-line around flywheel and bar, making the lashing very strong and secure and crossing the wire back of the wheel so it will not slip off. Be careful about the crossing, for there will be a heavy pull and the wire will slip if it can. Then tighten up on the bolt and strike it with a hammer, as in pulling a wheel, until the flywheel loosens.

As before, look out for the jump when the wheel comes off. The wheel is heavy and can do damage if you are not prepared for it.

The same kind of a temporary affair can of course be used for pulling road wheels or anything else. For flywheel work rope is not good. It has too much spring and stretch.

In axles in which the shaft is not keyed in the wheel hub the process will differ. In a full-floating axle it is not necessary to jack up unless a wheel is to be taken off. The removal of the hub cap and the driving clutch will allow the shaft to be pulled out.

Bearing Replacement.

Bearing replacement differs considerably according to the type of bearing and the details of axle construction. As a rule, such work has to be done so seldom that it is worth while to let the repairman do it.

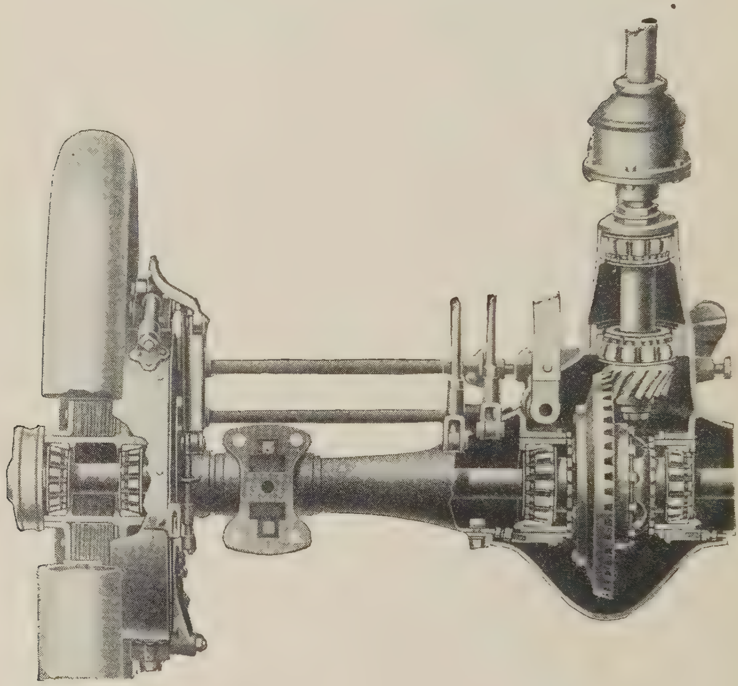
Axle Lubrication.

Rear axle lubrication should be given special attention. The gears have heavy work to do. The bearings carry a heavy load and need the right lubrication to give normal wear. If the lubricant is too light it will not properly serve the gears and will work out of the housing. If too heavy it will not be properly distributed.

Where grease cups are used the main thing is to see that they are kept filled with the right grease and that the grease is clean. Take particular care to keep the grease clean when putting it in. It is a very easy matter for dirt and dust from the axle to get into the grease

when filling up, and once in the axle or the bearings dirt stays there until the whole system is cleaned out. Always carefully clean the outside of a grease cup before filling it up.

Fortunately the care of axles is very simple. All that is necessary is to follow directions and use the specified lubricants at the specified times. If this is done conscientiously axle trouble will be a thing unknown, except in rare cases.



LUBRICATION OF THE REAR AXLE

The main driving gears and other bearings are oiled by a lubricant which should be carried in the differential housing. The bearings carrying the end of the axles on which the wheels are mounted may be packed in grease or lubricated by grease cups.

How the Rear Axle is Driven.

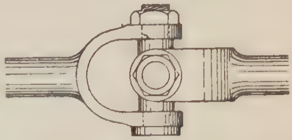
The connecting link between the gearset and the rear axle is the propeller shaft and its accessory parts. In some cars however, the gearset is mounted as a unit with the rear axle and the propeller shaft runs from the clutch on the engine to the rear axle gearset.

Some form of flexible connection is needed because the rear axle, being connected to the frame of the car by springs, has vertical movement with relation to the frame. So sometimes the rear axle is directly in line with the gearset, sometimes it is higher and sometimes it is lower, according to load and road conditions.

The requisite flexibility is obtained by using one or more universal joints.

Universals.

The conventional form of universal joint has a cross-shaped central member. The ends of the shafts to be flexibly joined are forked, the forks being just wide enough to take in two diametrically opposite arms of the cross. One pair of fork arms is pivoted to one pair of cross arms and the remaining pairs are similarly pivoted. This joint allows the connecting shafts to move in any direction and permits drive to be transmitted through an angle.

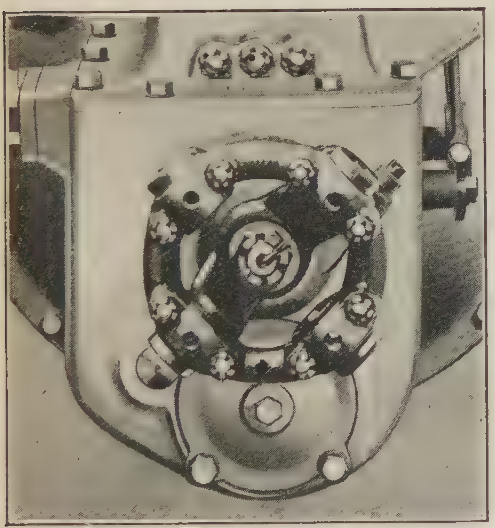


A UNIVERSAL JOINT

Up and down motion is possible at the same time that this joint is transmitting its rotary power.

There are a great many different forms of universals, but, dissected, they all will be found to work practically on the same principle.

The work of the universal is very severe and it has to be well made to stand up. It is always enclosed as tightly as possible in a housing or casing that holds lubricant.



A UNIVERSAL AT THE REAR END OF THE GEARSET

This is used to connect with the forward end of the driving shaft. Two universals on a driving shaft equalize the difference in the rotating speed, and prevent vibration.

It is of the greatest importance to see that there always is plenty of lubrication. Otherwise the joint will give trouble in a surprisingly short time, no matter how well made it is.

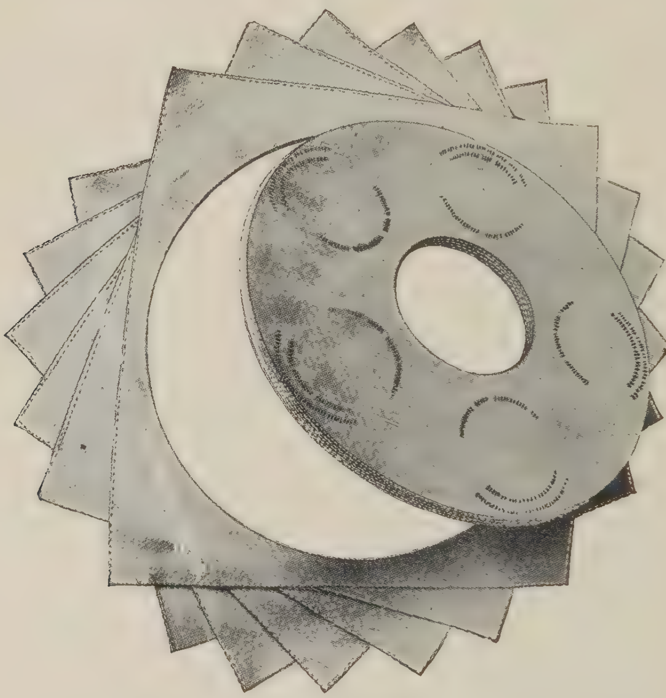
A worn universal causes a knocking that is heard only when the car is running, and that occurs only at times. It is apt to be deceptive and often is mistaken for an engine knock. Before blaming the engine for a knock that occurs when running, examine the universals.

The universal joint has a fault of operation in that, when working at an angle it drives a little faster during one part of a revolution than another, so that there is constant acceleration and retardation which occurs so rapidly as to set up a certain amount of vibration. This is remedied to a large extent in many cars by the use of two joints, one at each end of the propeller

shaft, so set that when one joint is moving at its highest rate the other is moving at its slowest.

Remember that the universal joint is one of the hardest-worked parts of the car. All you can do to protect it is to see that it is always well lubricated, that the housing is tight and to drive the car sensibly. Forcing the engine to labor on high gear on grades where the gears should be shifted is very hard on the universals.

In most joints there are bushings where wear occurs, and these can be renewed when worn. Renew them when they need it.



HOW A FABRIC UNIVERSAL IS MADE
The layers of fabric are cemented together in different positions so that the "grain" will pass in all directions and produce a uniform fiber.

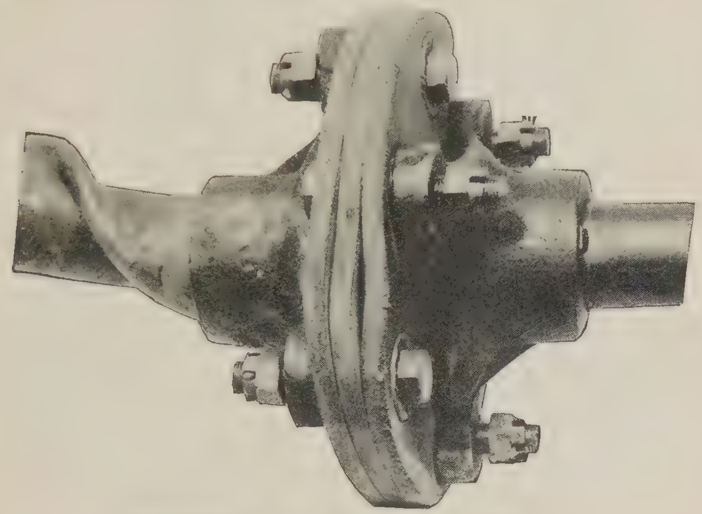
Flexible Disc Universals.

A type of universal joint that has received much attention of late years is the flexible disc, in which there are no bearings and no frictional parts whatever. This type of coupling is an old one, however, and has been used in machinery other than automobiles for many years.

The shafts to be jointed are fitted with "spiders" having either two or three arms each. The spiders are bolted to discs of a special rubber-and-fabric type vulcanized together and having greater strength than leather, which was used in the older flexible joints. The spiders

are placed with the arms of one, half way between the arms of the other. The flexibility of the fabric discs between the arms gives the joint the necessary play. Several discs are used in layers, commonly three.

Such a joint is absolutely noiseless and is not subject to wear in the ordinary sense of the word, and does not develop play. Its action is exceedingly smooth and satisfactory.



STRENGTH OF THE FABRIC UNIVERSAL

The left-hand portion of this has been twisted by the power applied to the right-hand portion of the transmission through the fabric universal, without material damage to the latter.

Joints on the same principle have been made with steel discs instead of leather or fabric, but in most cases have been found less satisfactory that the fabric type.

Fabric joints are unaffected by dust and dirt and need no lubrication or other attention.

Propeller Shaft Arrangement.

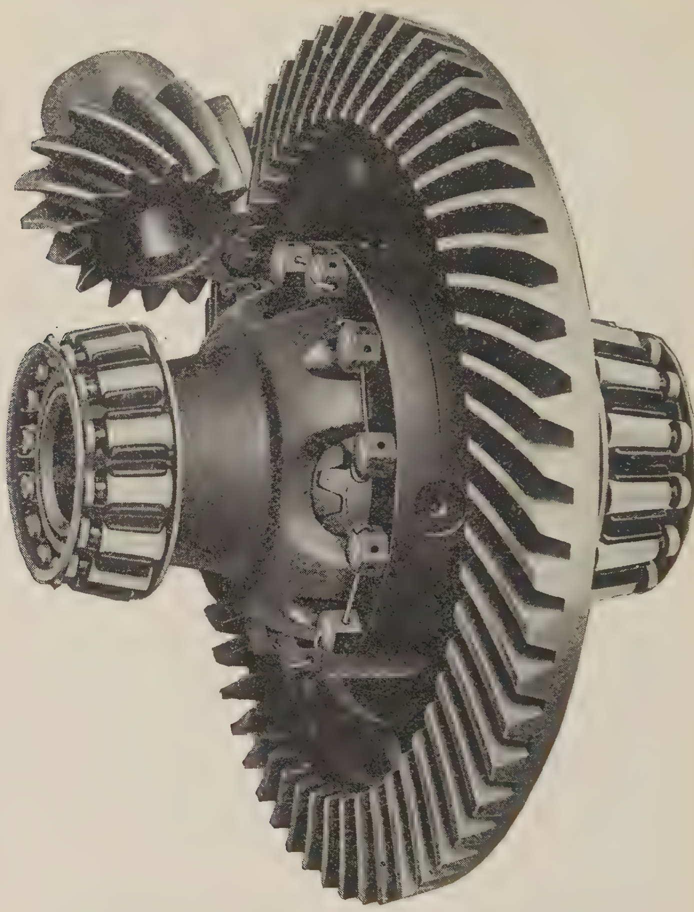
The arrangement of the propeller shaft depends largely upon the method of transmitting drive from the rear axle to the frame and body of the car; it must be remembered that it is the rear axle that is driven by the engine, and the rear axle has to take the rest of the car along with it.

In what is called the Hotchkiss drive the rear axle pulls the car along by the springs.

In another type of drive the propeller shaft is enclosed in a heavy tube of steel which is rigidly attached to, and to all intents and purposes is an extension of, the rear axle housing. The forward end of this

tube is jointed, usually at the rear end of the gearset housing, but always exactly in line with the universal joint. Thus the push of the rear axle is delivered to the rear end of the gear housing.

Sometimes a pair of rods takes the place of the tube, the rods running



THE REAR DRIVING PINION AND MASTER GEAR
The type here shown is of the spiral bevel shape in which the teeth are curved slightly. This produces an exceedingly quiet-running gear.

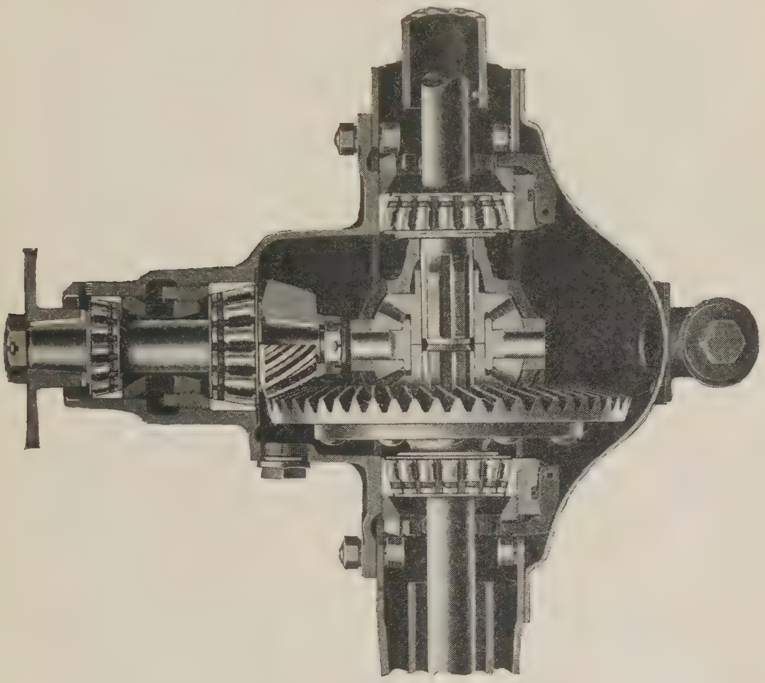
from near the ends of the axle housing to a point near the universal, forming a triangle. The principle is the same.

What Final Drive Is.

Final drive is the drive from the propeller shaft to the rear axle, commonly through bevel gears.

Two types of bevel gears are used, the ordinary or straight bevel and the worm bevel, sometimes called a spiral bevel. In the straight bevel the teeth are cut straight across the beveled face of the gear. In the

worm bevel they are cut at an angle. The advantage of the worm bevel is that the teeth come together gradually, contact beginning at one end of a pair of meshing teeth and extending progressively to the other end. In the straight bevel the teeth come together perfectly parallel. The result in the latter case is a little clash and noise, the extent of which depends upon the excellence of the gear-cutting and the condition of the teeth, while in the worm bevel operation is silent.



REAR AXLE ADJUSTMENTS ARE IMPORTANT

Each bearing should be set properly and the meshing gears should be so placed that there is sufficient play between them to prevent wear. A spiral bevel gear will run quietly even when it is improperly adjusted.

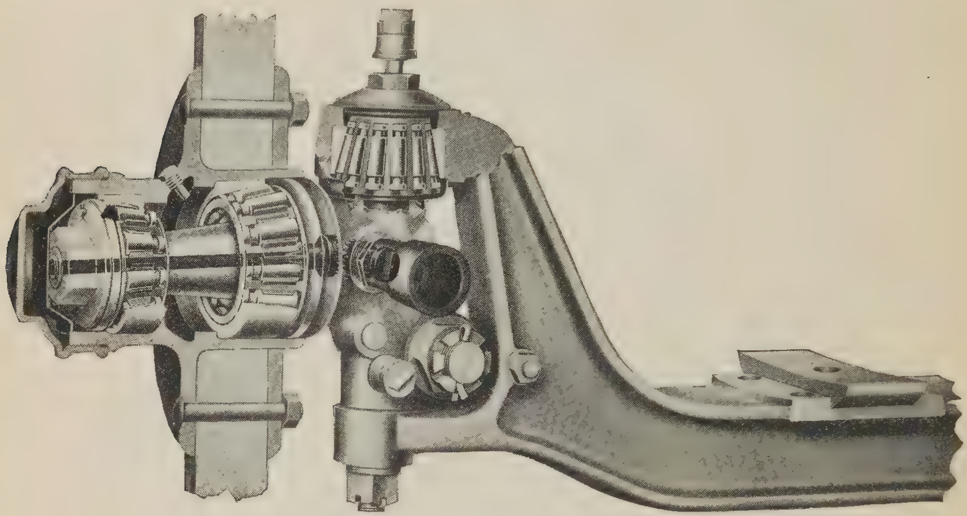
Adjustment is often provided for the final drive, and if the gears get noisy, the repairman should be called upon to adjust them. The spiral bevel gear produces an exceedingly quiet running rear axle, but one of the dangers from such a design lies in the fact that even poor adjustment will not produce the usual warning noise when the gears are run. In other words, bevelled gears of this type may be poorly adjusted without any indication other than that which can be obtained by close inspection.

Front Axle Construction.

The front axle is a "dead" axle, which is to say that it does not turn with the wheels as do the driving shafts of the rear axle. The wheels

always turn on short "stub" axles pivoted to the main axle to permit steering. All that is necessary is to mount the wheels on bearings so that they will turn freely.

Adjustment for the front wheel bearings is usually provided, and



A TYPICAL FRONT AXLE AND STEERING KNUCKLE CONSTRUCTION

The front wheel bearings should be packed in grease and the grease cup in the steering knuckle should be screwed down frequently; the tube-like projection in the spindle is to be connected with the speedometer shaft which, in this design, is driven by a small pinion and shaft extending through the front axle stud.

the wheels should be kept adjusted. The wheel should be so free that the weight of the tire valve will be sufficient to move it easily, but it should have no shake—or at most, just a suspicion of shake.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER III, SECTION III

Why a car has a differential.

What the principle of the differential is.

How to demonstrate the differential principle.

How a differential is constructed.

Why some cars have no differential.

What fault the ordinary differential has.

How to care for the differential.

What a semi-floating axle is.

What a three-quarter floating axle is.

What a seven-eighths floating axle is.

What a full floating axle is.

How to care for the rear axle.

How to make a wheel puller.

How to use a wheel puller.

How to care for grease cups.

How the rear axle is driven.

What a universal joint is.

How to care for universal joints.

Why a universal joint may knock.

How propeller shafts are installed.

How the rear axle drives the car.

What Hotchkiss drive means.

What final drive means.

What types of bevel gears are used.

What a worm bevel is.

How the front axle is constructed.

How axles should be lubricated.

CHAPTER IV

SPRINGS

Types of Springs.

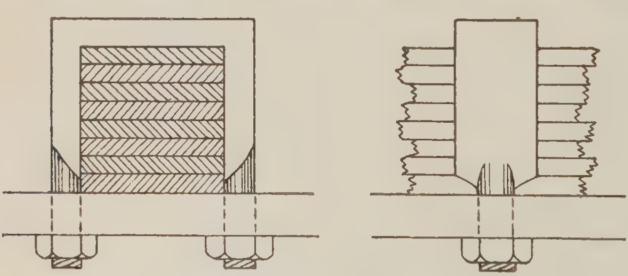
A large number of types and combinations of spring suspensions have been used in automobile construction, and in some cases exceedingly complex and expensive systems have been tried with the idea of making the car ride more easily. None of the more complex arrangements have survived, however. The simpler forms give excellent results and are very satisfactory when the design is good and the materials right.

The most commonly-used spring is the SEMI-ELLIPTIC. Adding half of a semi-elliptic spring at the top makes it a THREE QUARTER ELLIPTIC. Two semi-elliptic springs, one above the other with their concave faces in, make a FULL ELLIPTIC SPRING. A CANTILEVER spring is a single spring, usually longer than a semi-elliptic, with one end shackled to the frame of the car, the other end attached to the rear axle housing and the middle pivoted to the frame.

In some cars the springs, instead of standing parallel with the frame, are placed crosswise. Usually such springs are like long semi-elliptics. PLATFORM springs have been used, and are still seen on a few cars. These are crosswise springs, either connected to the body and rear axle, or attached to the rear ends of the regular type of semi-elliptic side spring.

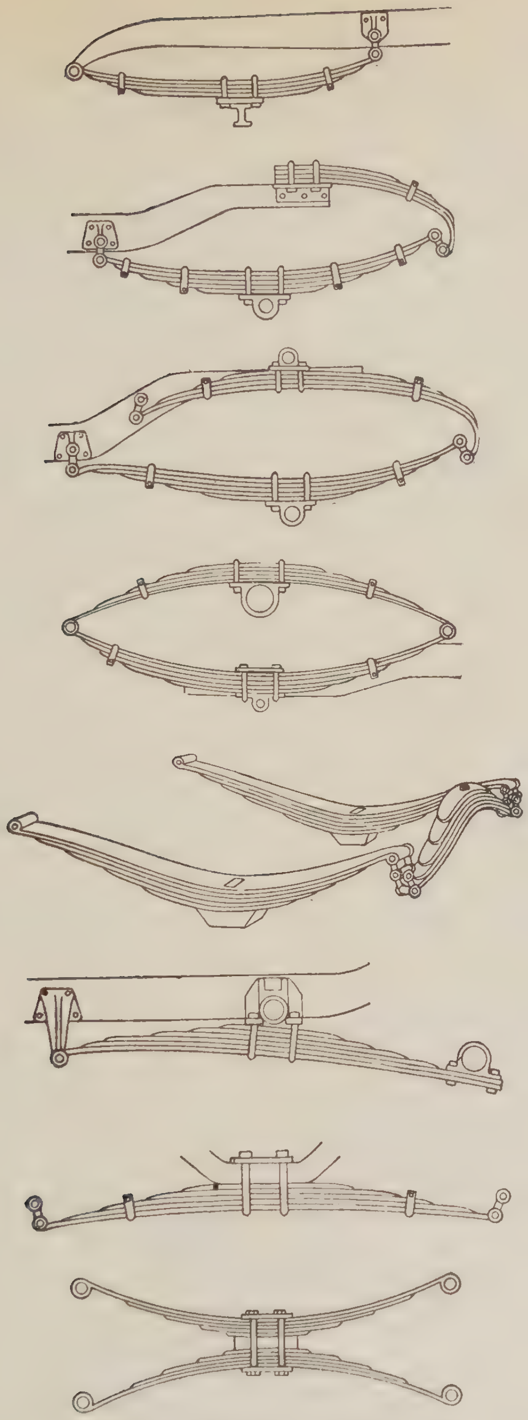
How Springs are Attached.

Springs are attached to the axles by clips, or U-bolts, which pass through holes in a pad or perch formed integral with the axle, or through a bracket. In the case of a semi-elliptic spring at the rear of the car one end is mounted on a stud fixed in the frame of the car or in a bracket on the frame, while the other end is connected with a similar bracket and



WHAT THE "U"-BOLT DOES

A leaf spring is composed of a series of blades. They should be clamped tightly together to prevent breakage and to hold them securely in place on the axle.



TYPES OF SPRINGS IN COMMON USE

Reading from top to bottom: one-half elliptic; three-quarter; elliptic; seven-eighths elliptic; full-elliptic; platform; cantilever; cross; double-cross.

stud through a short link called a shackle. The fixed stud at one end is necessary where Hotchkiss drive—drive through the springs—is used, though where the rear springs do not have to transmit any of the drive they may be, and sometimes are, shackled at both ends. Front springs are shackled at one end only because they have to hold the front axle in position, which they could not do if shackled at both ends.

Underslinging and Overslinging.

In most cars the springs lie on top of the axle. Where it is desired to reduce height as much as possible the springs are sometimes hung under the axle, which is called underslinging. The fastenings must be made heavier in this case because they have much more to do than simply hold the springs in position.

Holding the Leaves Together.

The time-honored way of holding spring leaves together is to drill a hole in the center and pass a bolt through, and this is still done in some cases. But because of frequent breakage due to the weakening effect of the bolt hole, various plans have been devised for holding the leaves together without it. In some springs the leaves are "humped" in the middle, the humps fitting together and preventing displacement. In others depressions are formed in each leaf, the other side of the leaf being pressed out to form a sort of lump. The depressions and lumps of the different leaves fit together so that the leaves cannot get out of place.

Importance of Spring Clips.

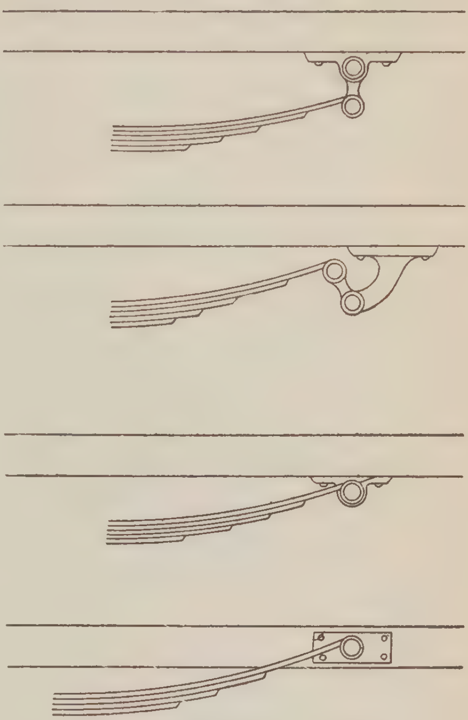
When the springs of a car rebound after having been compressed, as in passing over a bump in the road, the car may be thrown so high that there will be a pulling apart of the leaves if means are not taken to prevent it. This is a likely cause of breakage, because the leaves in such a case do not reenforce each other; practically the whole of the strain comes on the long or master leaf. So it is usual to put clips on the springs, which are simply small bands bolted around the bundle of leaves so they cannot spread apart and will all help in resisting the strain of a violent rebound.

A SPRING CLIP
This prevents the separation of the leaves on the rebound.

Spring Eye Construction.

The eye of a spring is the hole through which the bolt passes. From simply turning a loop in the end of the longest leaf and running a bolt

through it, spring makers have come to a much more refined and practical construction. The end of the spring is fitted with bushings, usually of bronze, and the bolts are of hardened steel, ground to an accurate finish to fit the eye, and grease cups or other means of lubrication are provided. Much ingenuity has been displayed in working out self-lubricating spring bolts. Bushings can be removed when worn and replaced with new ones, and this is of no little importance, as when looseness occurs in the spring eyes and bolts there is a good deal of rattling, to say nothing of the additionally rapid wear which always occurs when there is play in moving parts.



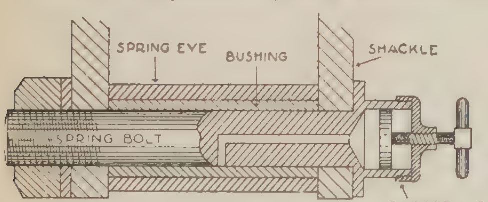
TYPES OF SPRING HANGERS

In the Hotchkiss drive in which there is no other positive connection between the axle and frame, one end of the connection must be attached directly to the frame without any linkage.

Care of Springs.

It is a real mistake to think that springs can get along without care. They are subject to a great deal of strain and have heavy work to do. And not only is there constant motion and friction at the eyes, but there is constant motion and friction between the leaves, which slide one upon the other every time the spring moves. Dust gets in easily, and so does water.

For the eye-bolts, use whatever means of lubrication may be provided just as conscientiously as you use any other means of lubrication on the car. They are easily attended to and there is no excuse for neglecting them.

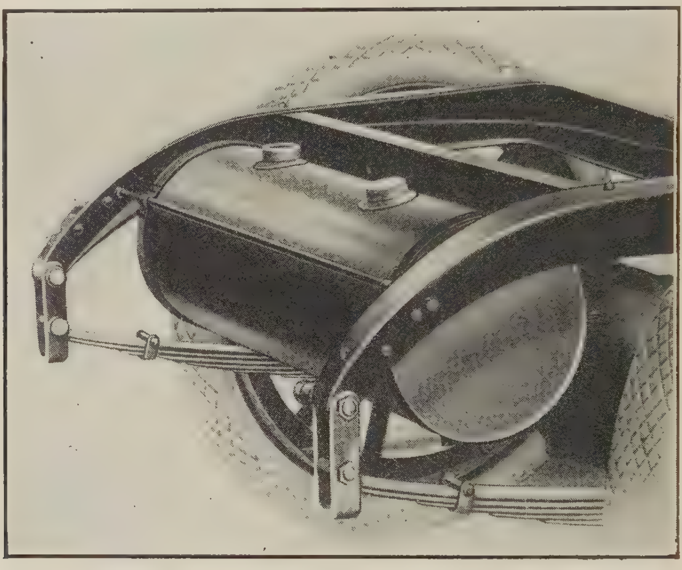


HOW THE SPRING BOLTS ARE LUBRICATED

Be sure the channel through which the grease or oil is forced is free. A clogged passage will produce a squeaking and badly worn bearing.

There should always be lubricant between the leaves. The simplest way to lubricate the spring leaves is to use a spring spreader to force the leaves a little way apart, and then introduce the lubricant. There are many good spreaders on the market, and some of them are so designed that they carry the lubricant into the spring.

About the best form of lubricant for spring leaves is a graphite grease. There are several special graphite lubricants put up for this purpose, and they are very satisfactory. Graphite and oil mixed to a pasty consistency is very good, however, and in the absence of graphite ordinary engine oil will keep the springs lubricated for some time. One of the advantages of good lubrication is that water and dust are prevented from entering between the leaves. Water causes rust and harsh action, and springs that are rusty are always harder riding than springs



A TYPICAL REAR SPRING SUSPENSION

These springs are of the semi-elliptic type and as they flatten the hanger at the end moves backward to allow for the straightening of the upper leaves of the spring.

that are clean and well oiled so that there is a minimum of sliding friction.

The spring leaves can be more easily separated if the car is jacked up from the frame. A jack placed under the axle serves only to compress the spring leaves the more. If the lifting power is placed under the sill of the frame however, the tension of the leaves will carry the weight of the axle and wheels, which in itself, is sufficient to separate the leaves so that a thin-bladed knife, or a special grease gun may be employed.

Why Springs Break.

A good spring, kept in good condition, well lubricated and well tightened in place, will rarely break. If, however, the U-bolts are allowed to loosen up, breakage is very likely to occur. It is rather

difficult to provide locks that will permanently prevent the loosening of these nuts because of the heavy strains and the constant movement. Therefore the nuts should be gone over with a wrench every 1,500 or 2,000 miles, and if there is any slack it should be taken up. See that the lock-nuts are well screwed down.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER IV, SECTION III

What different kinds of springs are used.

How they are attached.

What under-slung and over-slung means.

How the leaves are held together.

How springs are prevented from breaking.

How the spring eye is lubricated.

Why care is necessary.

How to lubricate the spring leaves.

How to jack up the car to lubricate the leaves.

Why springs break.

Why the spring clips should be kept tight.

CHAPTER V

THE WHEELS

Types of Wheels.

Wood, wire and disc wheels are used in automobile service, and all give satisfaction. So far the wood wheel is greatly in the majority, though there is considerable evidence of growth of the use of metal wheels. Wood wheels are built on the principle of the type of wheel used in artillery service, and therefore are known as of the artillery type. Wire wheels are now very different from their prototypes, which were simply enlarged bicycle wheels. A variety of systems of spoke arrangement have been introduced. Disc wheels, as the name implies, are wheels with steel discs in place of spokes. In some cases light steel discs are applied outside the spokes of wood wheels to give the appearance of disc wheels. These, however, are disc wheels only in looks.

How to Care for Wood Wheels.

Wood wheels will stand a tremendous amount of hard work with very little care. In dry weather the shrinkage of the wood is likely to cause a little looseness, which causes the wheels to creak more or less. This is readily cured by the application of water. A car that is washed at reasonably frequent intervals rarely has creaking wheels. Wheels that are very old or very much dried out can be made tight by removing the metal hubs and driving wood wedges between the ends of the spokes. In doing this do not taper the wedges, but make them of the same thickness from end to end, just tapering one end enough to make it enter easily. Coat the wedge with glue before driving it.

Replacing broken spokes is a job for the skilled wheelwright only. It involves a good deal of trouble and not infrequently the new spokes must be shaped altogether by hand. In wheel manufacture all the shaping is done by machinery.

Truing Wire Wheels.

Barring accidental damage, wire wheels are not likely to develop any trouble other than possible getting out of true. If a wheel is out it can be trued up without much trouble. Remove the tire and rim.

Spin the wheel on its bearing and hold a piece of chalk so that it will mark the place where the wheel wavers. Slightly loosen the spokes on the side where the mark appears and tighten the spokes on the opposite side. The spokes where the rim is most out must be turned the most and the others less and less, so that no change will be made in the part of the rim that is in shape.

Watch carefully for signs of rust, and do not let it spread. Wire wheels are usually so well enameled that they are well protected.

One of the advantages of the wire wheel is that it is made demountable, so that a whole wheel, tire and all, can be changed in less time than it takes to change a tire.

Do not allow wheels to run out of true. It causes extra wear on the tire at the point where the wheel is out.

Lining Up Front Wheels.

When the front wheels are pointing straight ahead they should be exactly the same distance apart at the front as they are at the back, measuring at the tire at the height of the center of the hub.

In some cars the front wheels are purposely placed a little closer together at the front than at the back, the idea being to compensate for the tendency of the wheels to spread apart when running. The difference is from a quarter to three-eighths of an inch. If the wheels were originally set this way, leave them "gathered."

There are two ways of establishing measuring points. One is to hold a sharp point against the center of the tire as the wheel spins and make a light mark all around, taking great care that the point does not shift while this is being done. If the tire has an uneven surface it will not matter, because the scratch on the high spots will do. The other is to measure between the edges of the rims. The former is the most accurate because the rims may be a little out of true.

Do not try to measure with a string because the stretch will throw you all out. Use a wood trammel, which is a bar with a stationary arm at one end and an adjustable arm at the other. The stationary arm is simply a piece of wood four or five inches long nailed or screwed to the bar at right angles and cut to a point. Make the movable arm in the same way, but put it in place with a single screw so that it can swing stiffly. Attach it as nearly as possible at the right point, and it will only be necessary to shift it a very little. The distance between the points will be about 56 inches, measuring to the centers of the tires.

Be very careful to do your measuring at the hub center line. In many cars the front wheels are closer together at the bottom than at the top, so that the measurements would be misleading if not made at

the proper height. It may be mentioned that the "toe-in" or drawing in of the bottoms of the wheels is done to make steering easier. The wheels are so slanted that the center of the tire, where it rests on the ground, is exactly under the center of the steering pivot. The result is that the wheel does not tend to pull out of a straight line.

If you find that the wheels are not parallel, adjustment can in most cases be made by lengthening or shortening the tie-bar between the steering knuckles. Shorten the bar to draw the wheels together at the back and lengthen the bar to draw them together at the front.

Be sure the wheels are pointing straight ahead. If they are not you will be away out, for the wheels are not, and should not be, parallel when turned. This is because the inner wheel, in making a turn, describes a smaller arc than the outer wheel, and so must be turned at a greater angle. The steering gear is arranged to take care of this.

There are two very good reasons why the wheels should be in perfect adjustment. One is that the steering is affected if they are out, and the other is that there is severe wear on the tires because of the scraping action. This may result in amazingly poor tire service, and the tire people know it very well from experience. So don't blame your front tires for wearing out too fast unless you are sure the wheels are lined up.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER V, SECTION III

What types of wheels are used.

How to care for wood wheels.

How to stop the creaking of wood wheels.

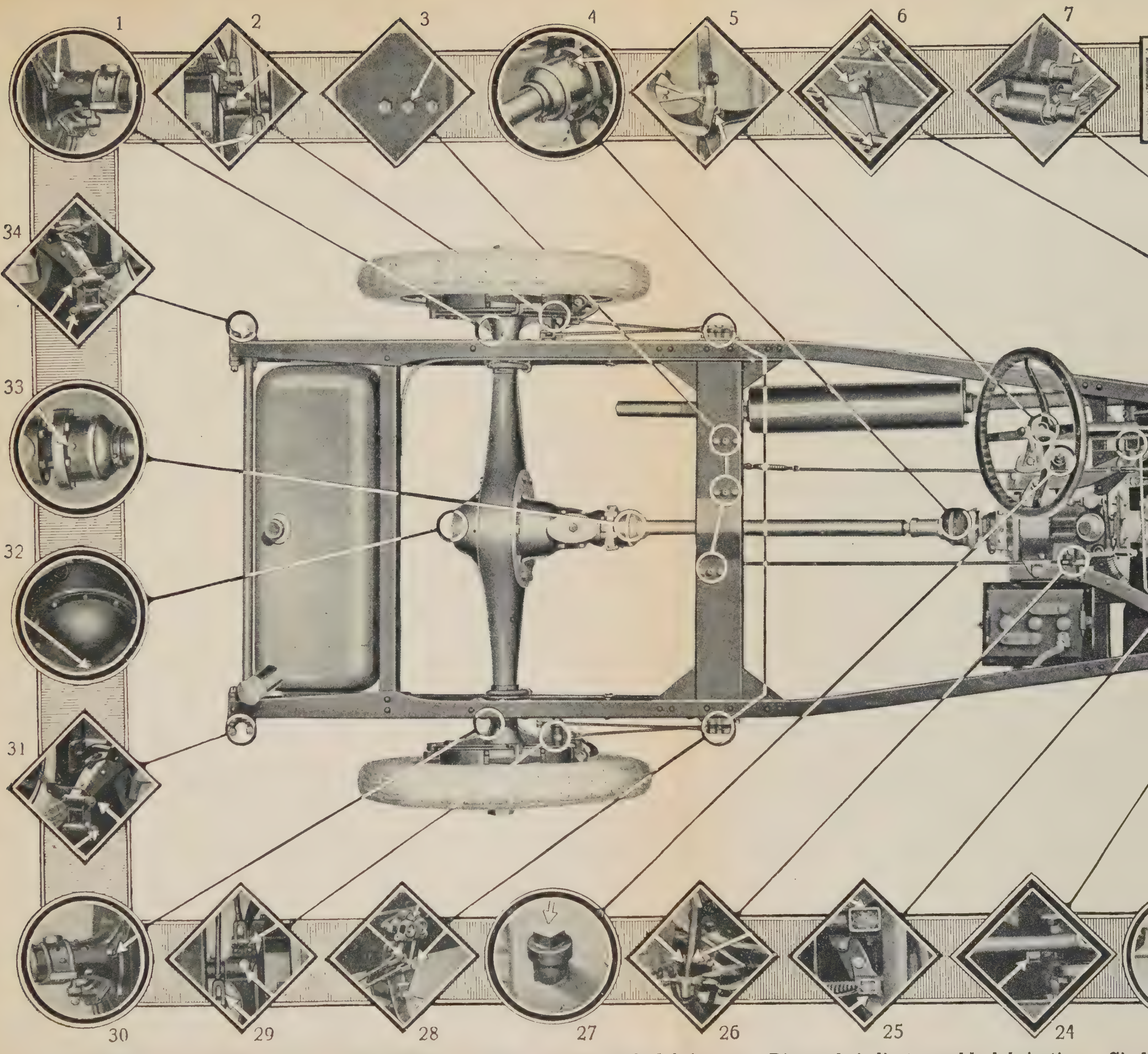
How to true up wire wheels.

How to line up front wheels.

Why front wheels should run true.

Why front wheels "toe in."

CHASSIS LUBRICATION CHA



LUBRICATE YOUR CAR AS SPECIFIED—Squares indicate daily lubrication. Diagonals indicate weekly lubrication. Circl

CHAPTER VI

THE BRAKES

Why Brakes are Vital.

To appreciate the importance of the brakes it is only necessary to imagine driving at good speed and suddenly be deprived of the brakes when a stop is necessary. Without brakes the car is helpless when it comes to control, and the combination of weight and speed is such that the brakes are called upon to do service so severe that the average user has little idea of what it amounts to. Brakes are necessarily well and strongly made. They are subject to much wear, however, and it is abso-

EXTERNAL BRAKE-BAND

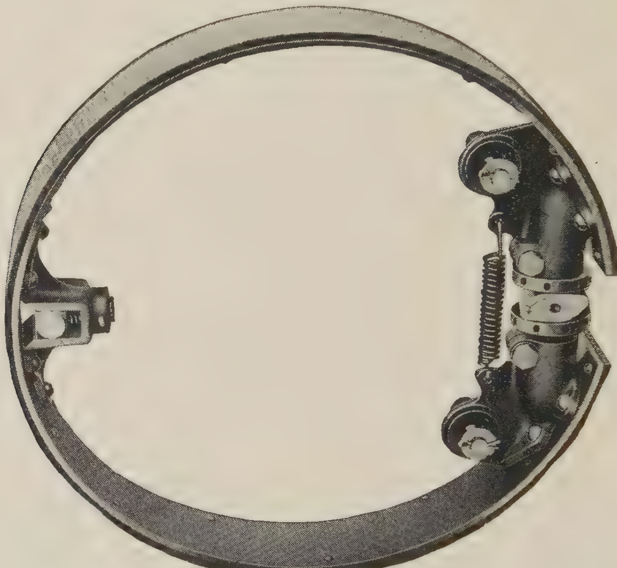
The lining is riveted to this flexible steel strip. The levers operated by a pedal contract this band so that it grasps the outside of the brake-drum tightly.

lutely necessary that they should receive, not merely casual attention, but close and careful attention, to keep them in first class condition. The tremendous strains to which they are subjected makes it imperative that nothing should be wrong, that there should be no small imperfection that might lead to disaster at a critical moment.

To get a feeble sort of idea of the work of the brakes, try to stop

even a light car by opposing your weight and strength to it when rolling very slowly down a slight grade. Then think of the comparatively small dimensions of the brake parts and the enormous pressure they must withstand in creating the friction necessary. A fairly heavy car moving at only a fair speed will knock down a telegraph pole or a heavy iron lamp post.

The force required to knock down the pole must all be absorbed by the



INTERNAL BRAKE-BAND

This is usually operated by the emergency lever. The brake lining is riveted to the outside of the flexible steel strip, thus the cam or other action spreads the band so that contact is made with all parts of the inside of the brake band.

brakes in bringing the car to a stop, and good brakes will stop a car in a very short distance.

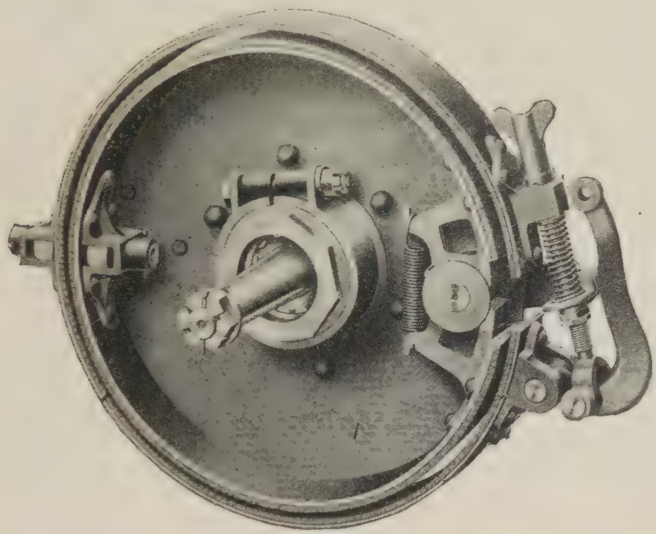
Perhaps you may gain a still better idea of the tremendous strain on the brakes when you realize that, to bring a car to a stop on a level roadway from, say, a speed of 25 miles an hour within 150 feet, the brakes absorb as much power in the form of heat as would be required to accelerate the same car from a standstill to 25 miles an hour in that same distance; and we know that a car which will reach a speed of 25 miles an hour in 150 feet is one that delivers tremendous power. Think of this when you are inclined to neglect your brakes.

See that your brakes are always in proper condition to do their hard work. They will not fail you if you do your part, and their condition may mean the difference between life and death.

Forms of Brakes.

The commonest form of brake is a band, lined with friction material of some sort, surrounding a drum upon which it is tightened by the brake-actuating mechanism. Or the band may be placed inside the drum, covered on the face next to the drum with friction material and expanded to cause friction.

There are always two sets of brakes, one for ordinary service, called the service brakes, and the other for emergency use, called the emergency brakes. Sometimes both brakes are mounted on the outside of



THE BRAKE ASSEMBLY

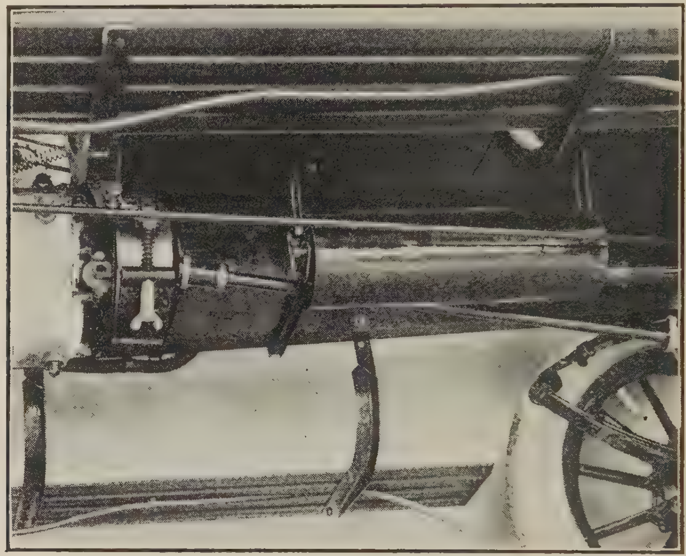
The space between the external and internal brake-bands accommodates the brake drum which is securely attached to the wheels. When both brakes are applied the drum is gripped firmly by the friction surfaces both inside and out.

the same drum, side by side; sometimes both are mounted inside the same drum, and sometimes one is inside and the other outside, the latter being perhaps the most common method and one that has the advantage of being effective without occupying much space. When this arrangement is used the internal brake is usually the emergency brake. The service brake is operated by a pedal and the emergency brake by a lever beside the gearshift lever, in the conventional system. The emergency brake may then be used for holding the car on a grade, or for locking it at the curb.

Occasionally a brake is placed on the final shaft of the gearset, just back of the gearset housing. This, however, is rather rare. It is called a transmission brake.

The brakes are applied by some form of joint by which the ends of

the band are drawn together to tighten the band on the drum. The drum, nearly always of pressed steel, is attached to the rear wheel hub or to the spokes of the wheel itself. There is a great variety of operating mechanism for drawing together the band ends—or for spreading them apart, in the case of an expanding brake. In the majority of cases a set of levers is used, but in many cars there are cams operated by levers. In all cases the arrangement is simple and readily understood if it is watched while being moved.



THE LOCATION OF THE TRANSMISSION BRAKE

This is generally placed at the rear of the gearset. The braking effect is considerably increased because of the application of this force on the geared-up shaft.

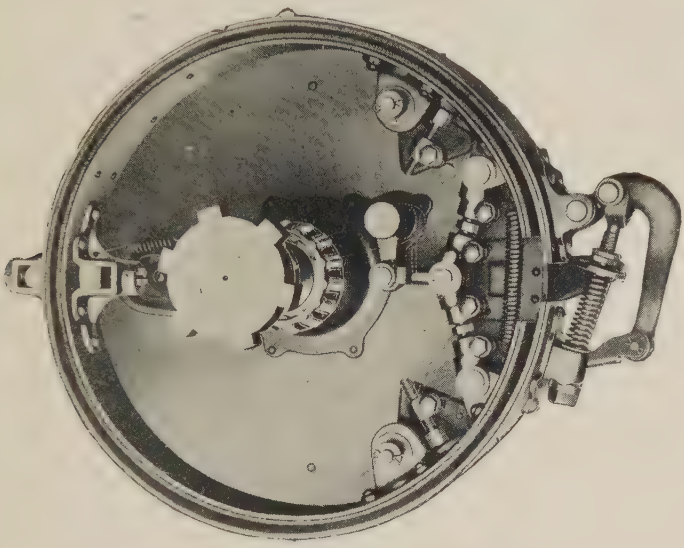
There is one car on the market in which the brakes are of a totally different type, being made like multiple disc clutches and enclosed in the rear axle housing. These brakes are very smooth and easy in action, and at the same time give a powerful grip when pressure is applied.

What Shoe Brakes Are.

Instead of flexible bands some brakes are made with solid shoes. Usually these are of the internal type. Sometimes they are faced with brake lining and sometimes they are not. Where no lining is used wear is taken up in the adjustment as far as possible, and then the old shoes are discarded and new ones installed.

Sometimes adjustment is not provided, in which case wear can be taken up by inserting thin steel liners at the points where the cams,

which are used to spread the shoes apart, push on the ends of the shoes. If new shoes are not readily obtainable further service can be got from the old ones by riveting on the friction surface a thin strip of brass to bring the shoe to its original diameter. The shoe is in two parts, hinged at the side opposite the opening. Shoe brakes are much less common than the band type.

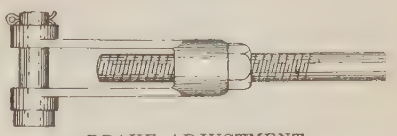


THE TOGGLE JOINT ACTION

When the short links are moved to force the toggle joint into a straight line a powerful leverage is produced which applies the internal brake with exceptional efficiency.

How Brakes are Adjusted.

When all the conditions are considered it is rather remarkable that brakes will wear as long as they do without adjustment, and a great deal of credit is due the manufacturers of brake lining for the work they have done in perfecting this part of the car's equipment. A great deal of heat is generated by the friction, and the lining has to stand this as well as the wearing tendency.



BRAKE ADJUSTMENT

A turn-buckle or a threaded clevis is provided to tighten or loosen the brake rod action.

In some brakes wear of the lining is compensated for by adjustments on the band-actuating mechanism itself. In others all the adjusting is done by shortening the rods leading from the operating pedal or lever to the mechanism at the band. In the latter case there is usually a turnbuckle on the rod, and it is only necessary to turn this to make the adjustment. Sometimes there is no turnbuckle, but in such a case it will be found that the end of the rod is fitted with a clevis or eye which

is screwed on the rod. By removing the pin the clevis can be screwed up on the rod, effecting the adjustment in the same way as with a turnbuckle.

The important thing in adjusting a brake is to get it set so that it can be applied by only a short movement of the pedal or lever, and yet to have the band entirely clear of the drum when the brake is off. It is important that the brake should not drag on the drum, for it causes a very noticeable retardation, wastes power and wears the lining fast. A dragging brake is readily detected by the heat it generates. If you suspect a brake is dragging, let the car come to a stop after a run without using the brakes, and then feel the drums. If they are hot loosen them up a little.

Equalizing the Brakes.

It is very important that both brakes should work with equal force. Otherwise you will not get the full effect, and the danger of skidding will be greatly increased. It also has a tendency to wear one tire abnormally, for one brake may lock the wheel so it cannot turn, dragging the tire along the road, while the other wheel turns.

To equalize the brakes, jack up the rear wheels so that both are clear of the ground, and adjust them independently until you can move the rear wheels with equal force when the brake is slightly set. Try moving the wheels with the brake set variously. Perhaps as good a test as any is to set the brake so that you can just move one wheel by exerting all your strength, and then set the opposite brake to the same standard.

In many cars there are automatic equalizers so that any slight difference is taken care of. If there is a very great difference in adjustment, however, there may be faulty action despite the equalizers. The service brakes are usually the ones automatically equalized.

Curing Brake Troubles.

Brakes very often squeak disagreeably when applied, and this can usually be cured. Put two or three drops—not more—of oil on the drums, spreading it, if possible, with the fingers. Do this about once a week. Watch the brakes carefully to note the effect. If there seems a tendency to slip and hold weakly, use less oil next time. Apply the brakes as soon as possible after putting on the oil to note the effect. On a small car use less oil—perhaps only a drop. Care must be used, for only a suspicion of oil is needed. This is a plan that has been used with a good deal of success.

If the brakes slip when they are properly adjusted, see if oil is

getting to them from the rear axle. If it is, find the leak and stop it. Wash the brakes with gasoline to get rid of the surplus oil.

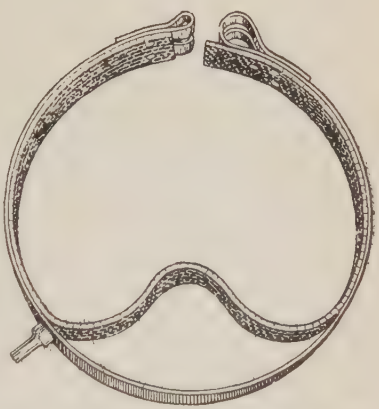
Oil will occasionally leak out from the rear axle housing onto one or both of the brake-bands. Felt washers are placed around the live axles in most cars to prevent this leakage, and in case the difficulty cannot be remedied otherwise, these washers will need to be renewed. It is usually the right hand wheel which suffers in this respect because of the crown of our country roads, and the American rule of the road which requires all vehicles to keep to the right.

Keep all the joints in the brake mechanism well lubricated, for they get a good deal of wear and need care. If there are grease cups, see that they are properly filled, taking all precautions to exclude dirt. Turn down the cups as often as the instruction book directs.

Relining Brake Bands.

Relining the brake bands is a job that is not hard to do, though it is often a good deal of bother because of the trouble involved in taking down the assemblies.

The first requisite is to get the right lining—the same lining as used originally is usually the best. If it is known positively that the original lining was not the best, it will pay to provide a better quality. Brake lining is not cheap, but it is worth what has to be paid for it, if it is good stuff. Cheap lining is not worth while. Be particular to get the right width and thickness; the latter is important because there is not a great deal of latitude in the clearance between the band and the drum. Brake lining dealers will tell you the proper width and thickness used on your make and model of car.



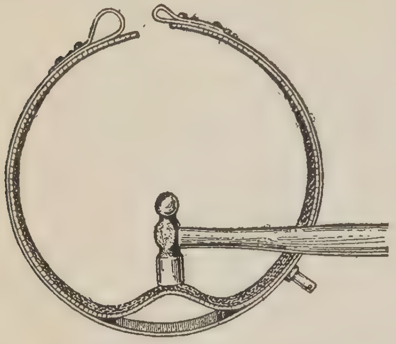
RELINING THE EXTERNAL BRAKE

The lining is cut about ⅜ of an inch longer than the band. This gives opportunity for compression of the lining, which makes an even fit all over.

The brakes themselves give warning as to when they should be relined. They will gradually fall off in holding power, despite adjustment. Do not wait too long. If you let the brakes go until the last gasp, the last gasp may occur just a minute too soon.

Cut off the heads of the old rivets with a hammer and chisel—the chisel should be sharp—and cut the new lining to the same length as the old. Use the same kind of rivets as in the old job. Under no circumstances use anything but brass or copper rivets.

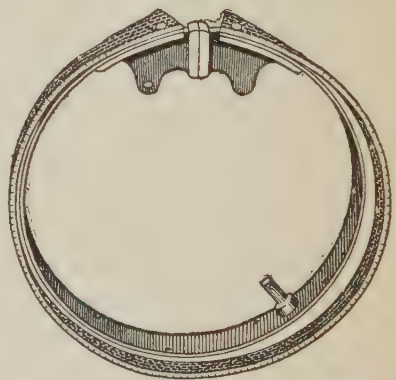
Holes for the rivets must be drilled in the new lining, and for this purpose it is advisable to use a special type of drill and countersink made for the purpose. It is difficult to make a good job of countersinking with the ordinary countersink, as the tool does not cut cleanly enough and does not make a recess of the best shape. The special tool is not by any means expensive.



COMPRESSING THE LINING

The "slack" as shown in the preceding cut is hammered down gently so that the lining is forced against all parts of the inside of the bráke band.

Drill and countersink the lining for the two rivets at each end and put the rivets in. Hold the lining in place, fitting snugly in the curve of the band, with a clamp, and drill and countersink the next two holes and put in the rivets, and so on, all the way round. This method makes it easier to get a good fit than any other that is easily used. Take great care not to get the lining humped between the rivets, and, on the other hand, not to stretch it too tight, or it will not lie close to the band and there will be a high spot that will drag until it wears down or the material is stretched by use. A good backing for the rivets when heading them over is a bar of iron or steel held vertically in a heavy vise. In any case use something as backing that will reach into the curve of the band and will not knock the band out of shape.



RELINING THE INTERNAL BRAKE

The lining should be cut ⅜ of an inch shorter than the band, and riveted at only two opposite corners.

External facings are more easily applied, but the principles are the same.

When the relined brakes are in place adjust them as closely as possible. The first wear will be rather rapid until the material gets down to a good working surface.

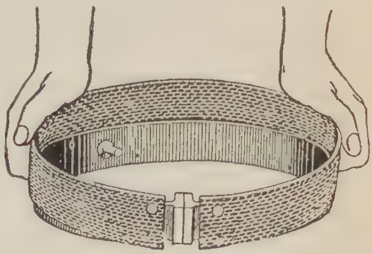
The brake linings in common use are made of asbestos and brass or copper wire woven together. A cheaper lining is made of cotton, but it is inadvisable to use this except for very light service.

Suggestions on Using the Brakes.

Use the brakes as little as possible. If it is necessary to slow down or come to a stop, let the car lose speed by itself and use the brake

gently to finish the job. This not only saves the brakes, but it saves fuel, for all the power that is put into the car, all the motion, is put into it at the expense of so much fuel, and it is a waste to run until the last minute and then use up the stored power by jamming on the brakes. Besides this, it is much more comfortable to ride in a car that is brought to a gradual, easy stop than one in which every stop is more or less of a shock and jerk. The tires, too, come in on this matter, for they have to supply the holding power on the road, and the more they are called upon to do the faster they will wear out.

Applying the brakes suddenly on a slippery road is a very prolific cause of skidding, and it should be avoided.



STRETCHING THE INTERNAL LINING

When the short lining is forced over the internal band it is stretched so that there are no humps or uneven surfaces

Do not think that the maximum braking power is obtained by locking the wheels so that they slide on the road. This is not the case, though the contrary belief is common. The greatest retarding effect is obtained when the brakes are on as hard as they will go without locking the wheels. Sliding the wheels is terrible punishment on a dry road, and goes a long way toward bringing the tire to a finish, for it starts a weak spot that may grow and develop.

Braking with the Engine.

The engine can be used as a brake, and is very effective under proper conditions. Without disengaging the clutch, close the throttle and retard the spark, and the engine, instead of pulling the car, will offer resistance and slow it down. Of course if the car is running very slowly you will get no braking effect in this way.

In coasting down long steep hills shift into a lower gear, leaving the clutch in. Let the car run down driving the engine. This saves the brakes and gives perfect control of the car. Long hills are exceedingly hard on the brakes. If they are used, apply emergency and service brakes alternately.

If the engine gives too much braking power, open the throttle a little, and it will be found that speed can be regulated in this way. Of course some gasoline is wasted, but it is wasted in a good cause, so to speak, and it is worth while, under the circumstances.

Don't throw the engine in as a brake suddenly on a steep hill, or it may give you too sudden a pull-up. A good deal depends upon the car in this matter, but a little experimenting will show the best way to handle it.

WHAT YOU SHOULD KNOW AFTER READING CHAPTER VI, SECTION III

Why brakes are vital.

Why the brake service is severe.

What kinds of brakes are used.

How brakes are adjusted.

Why brakes are equalized.

How to adjust the equalizers.

How to cure a slipping brake.

How to stop a squeaking brake.

How to reline brake bands.

Why good lining is important.

What tool to use for drilling and countersinking the lining.

How to adjust relined brakes.

Suggestions on using the brakes.

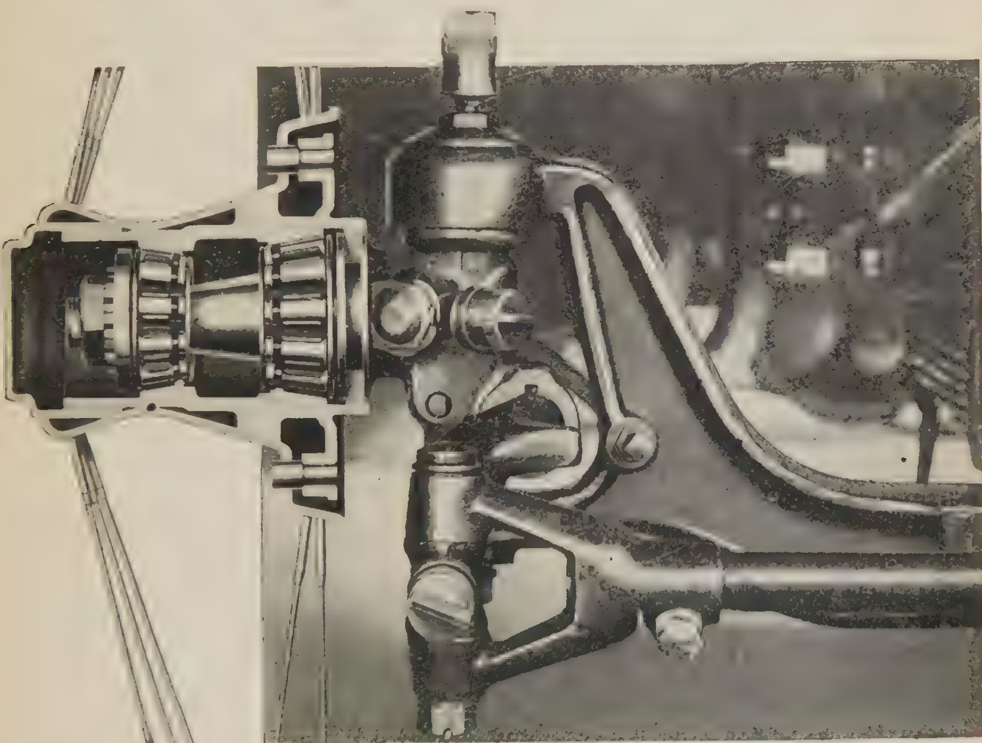
How bad braking wears the tires.

How to use the engine as a brake.

SECTION IV. THE STEERING GEAR

What the Steering Gear Includes.

The steering gear consists of the hand wheel, the post to which the wheel is fixed, some form of gearing at the foot of the column to transmit and reduce motion, the drag-link connecting the gearing with the knuckles and a tie-bar connecting the two knuckles so they move at the same time.



A VITAL PORTION OF THE STEERING GEAR

The wheel shown in section is mounted on a spindle which is turned by the steering wheel. The horizontal rod in the front connects the two road wheels so that they will turn in unison.

With the exception of the gearing at the foot of the steering wheel post there is little difference in the steering gear of cars except in matters of detail.

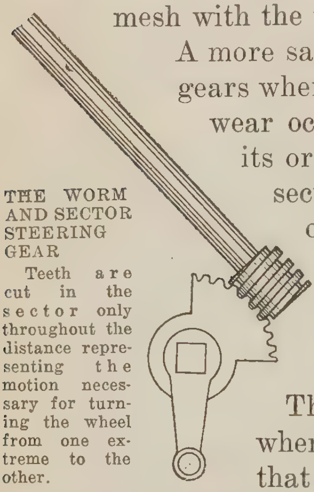
Types of Gearing.

The most popular type of gearing is the worm and sector, or worm and gear. There is a worm—a short screw of large diameter and

sharp pitch—on the post near the foot, and this meshes with a sector —section of a gear—or with a complete gear so that when the wheel, post and worm are turned the gear or sector, as the case may be, will be given part of a turn. An arm is attached to the sector or gear and the arm carries one end of the drag-link.

Adjusting Worm Gearing.

When a sector is used it is often mounted in eccentric bushings which, when slightly turned, bring the teeth of the sector into closer mesh with the worm and so take up wear.



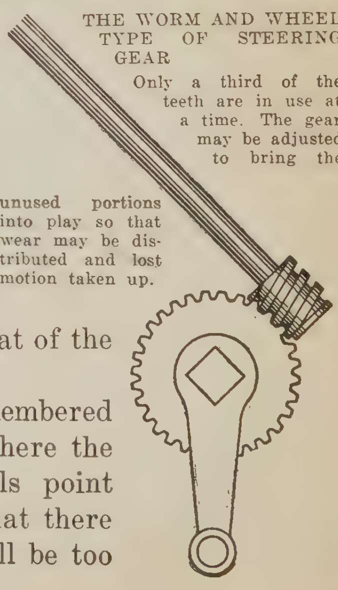
THE WORM AND SECTOR STEERING GEAR

Teeth are cut in the sector only throughout the distance representing the motion necessary for turning the wheel from one extreme to the other.

A more satisfactory method of adjustment is found in the gears where a full gear is used instead of a sector. When wear occurs the gear is given quarter of a turn from its original position, which brings a new and unworn section into contact with the worm. The worm is of hardened steel, and so wears but little. The range of movement is such that not more than quarter of a gear is used at a time, so that three adjustments can be made after the original section has been worn.

This matter of taking up wear is important, for when wear occurs it allows play or back-lash, so that the hand wheel can turn more or less, according to the amount of wear, without turning the wheels, which tends to make the steering uncertain.

Another type of gear has a large nut running on a thread on the steering post. The nut is held, so that it cannot turn, by sliding keys or by having a flat side, or flat sides, fitting against corresponding flats on the inside of the casing in which the whole gear is enclosed. Thus the nut is given a vertical motion when the hand wheel is turned. On the outside of the nut there is a row of teeth forming a rack, and these teeth mesh with the teeth of a sector, the action of which is precisely the same as that of the sector used in the worm arrangement.

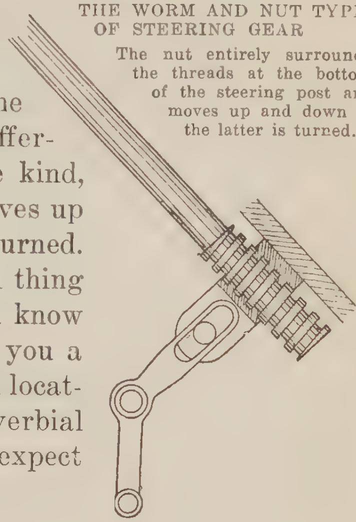


THE WORM AND WHEEL TYPE OF STEERING GEAR

Only a third of the teeth are in use at a time. The gear may be adjusted to bring the unused portions into play so that wear may be distributed and lost motion taken up.

In adjusting a worm gear it must be remembered that most of the wear occurs at the point where the parts come together when the road wheels point straight ahead. If adjustment is made so that there will be no back-lash at this point the gear will be too

tight when moved far to the right or left. So the adjustment is best made with the road wheels well to one side. The result must be a compromise between too much tightness and not enough. Beware of too much tightness when the wheels are swung over, or you may find that the gear will stick when "cramped" and perhaps get you into an awkward predicament.



THE WORM AND NUT TYPE OF STEERING GEAR

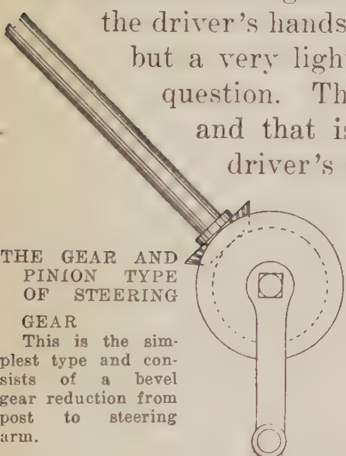
The nut entirely surrounds the threads at the bottom of the steering post and moves up and down as the latter is turned.

There are naturally many variations in the details of steering gears, without much difference, however, in general principles. One kind, for instance, has two nuts, one of which moves up and the other down when the wheel is turned. And there are various others. It is a good thing to know your steering gear as well as you know any other part of the car, which will help you a great deal in taking intelligent care of it and locating trouble if trouble occurs. With the proverbial ounce of prevention, however, you need not expect much bother.

Reversible and Irreversible Gears.

If a steering gear is so constructed that the hand wheel can be moved by force applied to the road wheels, the gear is called a reversible gear. If the hand wheel cannot be so moved, it is an irreversible gear.

With a reversible gear road shocks and vibration are transmitted to the driver's hands, and this is very tiring. In fact, in anything but a very light car it is so fatiguing that it is out of the question. There is a drawback that is even more serious, and that is that the wheel may be jerked out of the driver's grasp under certain road conditions, so that trouble may occur.



THE GEAR AND PINION TYPE OF STEERING GEAR

This is the simplest type and consists of a bevel gear reduction from post to steering arm.

Nearly all cars, therefore are fitted with irreversible gears, such as those described. Taking the screw and nut type as an example, the point is readily illustrated. The principle is simply that of a nut on a bolt. You can make the nut move up and down by turning the bolt—which corresponds to the steering post—but you cannot turn the bolt by pushing the nut up and down. The principle is the same in the case of the worm and gear or worm and sector construction, except that the threads are outside instead of inside, and are very much coarser.

Some light cars have a steering mechanism consisting simply of a small bevel pinion on the steering post meshing with a bevel sector carrying the arm connecting with the drag-link. This is a reversible gear, and so is the type in which the pinion on the post operates a straight rack.

Why Gearing is Used.

It might seem that the simplest and easiest way to construct a steering gear would be to merely attach an arm to the foot of the steering post and attach this arm to the drag link without the interposition of gearing of any kind. The first and obvious objection would be that such an arrangement would be reversible. There is another, however. A very slight movement of the steering wheel would give a wide sweep to the road wheels. In other words, the action would be too quick and the steering altogether too sensitive. Further, the driver would have very little leverage. So the gearing, whatever it may be, is introduced to "gear down," the result being that a considerable amount of steering wheel movement is required to produce a small movement of the road wheels. It usually requires about one and a half turns of the hand wheel to turn the road wheels from one side to the other as far as they will go. This has been found about the most satisfactory ratio in practice.

Steering Gear Bearings.

Steering gears are necessarily well supported in bearings, and this is important because of the constant movement and the considerable strain. There is a good deal of end thrust—force applied endwise to the steering post—and this is taken, usually, by ball thrust bearings. If the bearings are not adequate not only will wear occur rapidly, but the gear will work hard.

If the thrust bearings wear there will be up and down play in the steering post, and this will result in back-lash. Therefore there usually is an adjustment so that end play can be taken up. In a worm and gear or worm and sector steering gear there usually is an adjusting nut for the thrust bearings at the top of the gear housing. A clamping screw holds the nut in place. To adjust, loosen the clamping screw and turn the nut—usually to the right—until there is just a suspicion of end play—just enough to make sure that there is no crushing pressure on the bearings. Ball bearings, which are often used, will be damaged by too tight an adjustment here, though they will still roll fairly easily and the gear will seem to work well for the time being.

Steering Gear Lubrication.

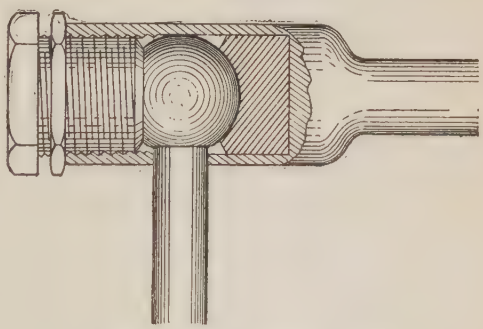
Steering gear lubrication is extremely important for the same reason that good bearings are important. As a rule the gearing is enclosed in a tight housing, which is packed with grease or a graphite compound. This lasts a long time, but has a tendency to dry and gum up or thicken, and should be thinned occasionally with a little lubricating oil. This is the part of the system that is most subject to wear, and the part in which the effects of wear are most apparent and undesirable.

Adequate means for lubrication are always provided, and instruction books give detailed information on the subject. A good steering gear that gets proper attention will give very satisfactory service, but even the best of gears will suffer from neglect, and will make the driver suffer, too.

Care of the Steering Gear.

It is obvious that derangements of the steering gear may easily lead to serious accidents. It is prudent, therefore, to say the least, to inspect the system frequently and carefully. See that all nuts and other fastenings are tight and that all cotter pins and other locks are in place. You can't tell whether a nut is tight or loose by looking at it. Put a wrench on it.

In making an adjustment where there is a considerable range, as in gears where adjustment is made by moving teeth closer into mesh, take care that the adjustment is not too tight, or undue wear and hard steering will result. Make the gear as tight as possible without causing it to bind in the least and, on the other hand, without leaving any more back-lash than can be avoided. Sometimes a trifle of back-lash is unavoidable.



A BALL AND SOCKET JOINT

This is placed at either end of the rod connecting the front wheel with the steering rod. It permits of play due to rough roads and yet transmits a positive motion.

The arm connecting the gear with the drag-link usually has a ball on the end fitting in a socket in the end of the drag-link, forming the familiar ball-and-socket joint, which permits movement in any direction and prevents binding. See that this joint is properly adjusted and, particularly, that it is well lubricated. A leather "boot" is generally laced around this to help keep in the lubricant and prevent the entrance of dirt.

Control Lever Arrangement.

The spark and throttle levers usually are mounted on the steering wheel, and form a unit with the steering system. Movement of the levers is transmitted through tubes running inside the column supporting the steering post. Sometimes through inadequate lubrication, these tubes become rusted or gummed with old oil or grease, when they may stick more or less. Apply preventative measures by seeing that they are oiled, if provision is made for the purpose or if there is any way of introducing oil. If rust and sticking occur, it is best to dismantle the column, take out the tubes, clean them and smooth them with emery cloth and coat them liberally with thin graphite grease when putting them back. In many cases the sector carrying the levers is mounted on a tube carried to an anchorage plate at the foot of the column, and this tube, which usually is outside of the lever tubes, also may rust. It may also come loose from its anchorage, so that the sector shifts and allows the levers to move when they should be stationary. The remedy will depend upon the manner in which the fastening is constructed, which is readily ascertained on examination.

WHAT YOU SHOULD KNOW AFTER READING SECTION IV

What the steering gear includes.

What types of gearing are in common use.

What a worm and sector gear is.

What a worm and gear is.

What a screw and nut gear is.

How to adjust the worm and sector gear.

How to adjust with eccentric bushings.

Why adjustment is important.

How a gear can be made too tight.

How reversible and irreversible gears differ.

Why the irreversible gear is the best.

Why a reduction gearing is necessary.

Why the steering gear bearings are important.

Why thrust bearings are used.

How to adjust thrust bearings.

Why lubrication is extra important.

How to take care of the steering gear.

Why a ball-and-socket joint is used.

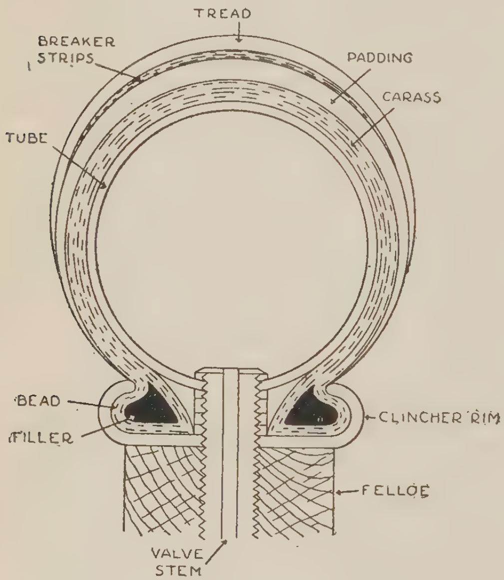
How to care for the spark and throttle lever tubes.

SECTION V. THE TIRES

The Construction of Tires.

Pneumatic tires are of two types, fabric and cord, the fabric construction being the more commonly used in the smaller sizes largely because it is less expensive in first cost than the cord tire.

The shoe of a fabric tire is built up on a foundation consisting of a number of layers of cotton fabric, five layers being about the minimum number used in ordinary construction. The fabric is "frictioned" with rubber compound which is forced in to the fibres by special machinery. This makes it possible to vulcanize the fabric very securely to rubber, as well as waterproofing the cotton and increasing its durability. Over the cotton fabric foundation there is a thick layer of very resilient rubber which helps give the shoe elasticity. This layer of padding, as it is called, is thick at the center and tapers down quite thin at the sides. Over the padding "breaker strips" are placed, these being strips of heavy fabric designed to strengthen the tread and give as much resistance as possible to puncture. The breaker strips are only wide enough to cover the part of the shoe exposed to puncture. Lastly and on top of all the other layers there is the tread. This is made of rubber in which strength is the main consideration, for it is the part that comes into direct contact with the road surface and must resist wear and tear and a great deal of friction and withstand the driving strains when used on the rear wheels. The composition of the tread rubber is exceedingly important and much depends upon it.



CROSS-SECTION OF A TYPICAL PNEUMATIC TIRE

The carcass may be composed of five or more layers of cotton fabric impregnated with rubber. A cord tire employs five or more cords crossing in all directions, instead of the cotton fabric.

When all the parts have been assembled the tire is vulcanized by heat the result being that the parts are joined together in a way that

is to rubber what welding would be to metal, forming a united mass. There are two general methods of vulcanizing, one process being moulding and the other wrapping.

In the moulding process the whole assembled tire is placed in a mould of iron and subjected to heat, steam jackets being used because of the facility with which the temperature can be controlled and the uniformity with which the heat can be applied to all parts. In the wrapped tread process the tire is wrapped with strips of fabric which hold it in shape while heat is applied. The marks of the fabric can be seen on the rubber, as a rule, in wrapped-tread tires.

There is considerable difference in the details of various makes of fabric tires, each maker having his own pet ideas which are developed and carried out according to his experience as to what is best. The foregoing, however, gives a good idea of the general system.

Cord Tire Construction.

A very different process is used in building cord tires. The main part of the shoe is formed by layers of cotton cords, impregnated with rubber, stretched from rows of wire hooks at the edges of the shoe. The layers are put on at an angle, and each layer is at an angle to the next. Between the layers of cords are sheets of rubber. Over the cords are breaker strips and then there is the usual tread section. The whole is vulcanized together.

The result of this construction is a tire that is very resilient and easy riding and that gives excellent mileage. Because of its rather high first cost the cord tire is used, as a rule, only on rather high-priced cars. They are popular for electric cars because of their resiliency and economy of power.

Repairs on cord tires can be made only by a competent expert. Don't try to repair your own cord shoes, and don't give the work to a man who is not experienced on cord tire work.

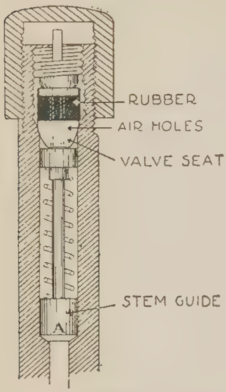
How Tires are Held on the Rims.

The edges of shoes are formed according to the kind of rim they are intended to be used with. In the clincher type there is a bead which projects into corresponding channeling in the rim, while in the straight side type there is no bead. In straight side tires steel wires or cables are usually vulcanized into the base to give additional holding power and prevent stretching. In any type of tire the pressure of air forces the shoe very tightly into place and it is held securely.

A CLINCHER RIM
The sides of the tire must be pried over the edges of the rim.

Valve Construction.

The tire valve is an important and hard-worked little part of the equipment. The construction looks a little complex, but it really is simple enough. The valve proper slides up and down on a central rod and is held against its seat by a light spring. Air passes through openings in the centre of the valve seat, the outside of which is packed air-tight against the wall of the stem by a soft rubber gasket. The valve is so placed that the pressure of air from the tire forces it against its seat. The spring is light enough so that the pressure of air from the pump will compress it and allow the valve to open.



A TIRE VALVE
This mechanism is inexpensive and efficient, and when the rubber wears the "inside," should be renewed.

Inner Tube Construction.

The business of the inner tube is simply to hold air. It does not require the strength of the shoe, for it is protected, but it must be tight. Tubes are interchangeable with the different makes of shoes.

Some tubes are moulded in circular form, but most tubes are of straight lengths of tubing joined together at the ends. The highest grade of rubber must be used, and some manufacturers have succeeded in producing tubes that will stand amazing tests.

Using Tubes of Different Sizes from the Shoes.

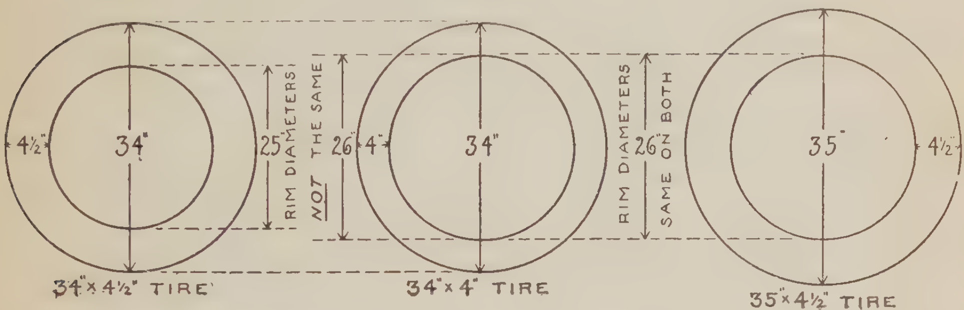
Sometimes the motorist will find himself in a position where he needs a new tube and cannot get one of the exact size specified for his tire. In such a case it is possible to use tubes of other sizes.

If the diameter of the inner tube is the same as the diameter of the tire *at the rim* the size of the tube may be smaller than that of the tire, within certain limits. It is said that stretching a tube half an inch over its nominal size does it no harm, and that it may be stretched an inch over its nominal diameter of cross section without injury. Certainly such stretching would do no harm in a comparatively short run, and would serve, perhaps, to help out of an awkward predicament. Going a little further, it is possible to use a tube of a size half an inch too large, if it is very carefully put in to avoid pinching. The larger the tire the less likely stretching is to harm it because of the greater total length of rubber over which the stretching is distributed.

Suppose you have a 34″ x 4″ tire and cannot obtain a tube of the same size. The rim diameter, or "the inside ring" is 34″ — 8″, or 26″. Consequently, a 35″ x 4½″ tube will fit a 34″ x 4″ shoe, with only

an extra ½″ of cross section. The main thing is to get the rim diameter the same.

A better fit could be obtained by using a 33″ x 3½″ tube in a 34″ x 4″ shoe. The rim diameter is the same, inasmuch as this is obtained by subtracting 7″ (twice the cross section), from the 33″ outside diameter, which gives us 26″. The ½″ stretch necessary in the cross section would not seriously affect the life of a tire.



HOW DIFFERENT TIRES OF DIFFERENT SIZES MAY BE USED

Remember that it is the diameter of the inside circle, or rim diameter, that counts in fitting a tire. Tire sizes are given in terms of their outside diameter however. Consequently, subtract twice the amount of the cross-section from the outside diameter to determine the size of the rim which it will fit. Rim sizes are mentioned, not in terms of their own diameter, but in terms of the outside diameter of the size of the tire for which they are intended.

On the other hand, a 34″ x 4½″ tube cannot be used in a 34″ x 4″ shoe because we find that the rim diameter of the former is only 25″, (34″ — 9″).

Following are the rim diameters of tires of commonly used sizes:

30 x 3	24 inches	34 x 3½	27 inches
30 x 3½	23 inches	34 x 4	26 inches
30 x 4	22 inches	34 x 4½	25 inches
32 x 3	26 inches	36 x 3½	29 inches
32 x 3½	25 inches	36 x 4	28 inches
32 x 4	24 inches	36 x 4½	27 inches
32 x 4½	23 inches	36 x 5	26 inches

Rim Construction.

The many kinds of rims that are in use may be divided into six groups.

The one-piece clincher rim is the familiar simple band of steel with its edges turned up to form flanges or "clinches" into which the beads of the clincher tire fit. These rims are rarely used for any but comparatively small tires because the beads must be stretched over the edges of the rim, and on a large tire this is extremely hard to do.

The quick detachable (abbreviated "Q-D") clincher rim takes the same tire as the plain clincher rim. The difference is that only one of the flanges is integral with the rim, the other being a separate part which can be slid off when the locking device is loosened, allowing the tire to come readily off the rim. This type of rim has made a vast difference in the handling of tires, especially in the larger sizes which are difficult to manage at best. The locking rings are made in a great many different forms.

The quick detachable straight side rim takes the beadless tire and has the same type of locking arrangement as the clincher, though the detachable part which holds the tire is of course of different form because of the different shape of the base of the tire.

The demountable rim is designed to be removed bodily from the wheel with the tire in place—that is, rim and tire are removed together. Some of these rims are so made that the tire cannot be removed until the rim has been taken off.

The demountable-detachable rim always permits the tire to be removed with the rim in place on the wheel and also permits tire and rim to be taken off together.

There are of course a great many detail differences in rims. In some rims of the detachable clincher type the inner flange or clinch is a separate part, as well as the outer clinch. Some rims are so made that either clincher or straight side tires can be used. On these, both clinches are removable. One side of the clinch is shaped to take the clincher tire base and the other side to take the straight side. To change from one type of tire to the other it is only necessary to reverse the rings.

Removing Tires from Rims.

Removing a tire from a rim is often a very unpleasant job, it may be said that in many cases a lot of trouble can be saved by keeping the rim in good condition and free from rust so that the tire will not stick if it is left on for a long time. Sticking can be prevented by rubbing the rim where the tire touches it—especially in the clinches and angles—with a mixture of graphite and water made into the form of a rather thick paste and allowing it to dry. There are a number of compounds on the market made especially for this purpose.

Another point is to keep the rim and its locking devices, whatever they may be, in good condition by abstaining from abusing them. Many rims are hard to manage simply because they have been unmercifully hammered and pounded until they have been forced out of shape. A certain amount of forcing is often necessary, but the rim is made to

stand it. The use of a hammer at joints where there is a close fit is a common cause of trouble.

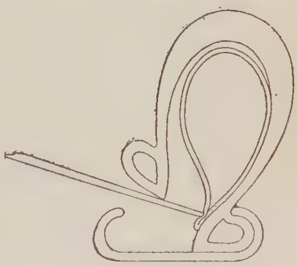
In removing a tire from a plain clincher rim the wheel is of course jacked up first of all. Then the cap is unscrewed from the valve stem and the lock-nuts removed so the stem can pass through the hole in the felloe of the wheel and the rim. Let all the air out through the valve.

The tire is started by prying the outer bead out of the clinch with a flat-ended iron. If the bead is badly stuck this operation may be very difficult, and in such cases one of the special clamp-like tools made for the purpose is exceedingly useful. When the bead is loose and free from the clinch an iron is inserted under it and it is pried up over the outer clinch at one point. A new, stiff tire is quite difficult to handle and longer levers may be necessary than with an old tire that has become pliable.

When the bead has been pried over the edge at one point, leave the iron in place and with another iron work along, raising the rest of the bead a little at a time until the bead is all off.

The next step is to remove the tube, starting at a point on the opposite side of the wheel from the valve. Lift the valve out last.

If it is only required to get at the tube it will not be necessary to take off the other bead of the shoe. If the shoe has to come off, however, it is removed over the outer clinch in the same way as the outer bead.



A PINCHED TUBE

In removing a clincher tire see that the tool does not project through and pinch the tube.

Take particular pains in removing a tire not to pinch or otherwise injure the tube. See that it is pushed out of the way of the tools.

To replace a tire it must be pried back in much the same way. Putting on as much of the inner bead as possible without tools, keep it close to the outer clinch at first while the last of the bead is pried over, a job which requires some little work. Then work the bead over into the inner clinch.

The inner tube comes next. Partly inflate it, so that it will hold its shape, though not enough to stretch it any, and put the valve stem in first and then the rest of the tube. Take great pains to have it lie properly in position and to see that no folds are made. This is "pinching" and generally results in a hole in the tube.

Dust the inside of the shoe with talc or French chalk. This prevents friction between the shoe and the tube and prevents their sticking together.

Only a light sprinkling is required. More than that may do positive harm by collecting and forming lumps.

Then pry over the outer bead. When the tire is inflated the beads will be pushed firmly and all the way into place.

Another way in which a tube may be pinched is to catch it under one of the beads. This is even more effective as a means of making holes to let out air.

Special tools for removing clincher tires are made in considerable variety, and some of them are exceedingly good as trouble and tire-savers.

Taking Off a Demountable Rim.

Loosen the bolts holding the rim in place, with the exception of the two nearest the valve, until the wedges can be moved out of the way of the rim. Keep the wedges out of the way by screwing the bolts up a little. Starting on the side of the wheel opposite the valve, work the point of a screwdriver between the rim and the steel band that is shrunk on and is part of the wheel. This is called the felloe-band. The rim will slip off at this point. Turn the wheel and lift the rim and tire off, taking care not to damage the valve stem as it comes through the hole.

Putting the tire and rim back on the wheel is simply a reversal of the taking-off process. Start by putting the valve in. In many rims there are small studs on the inner edge of the rim, and it is sometimes necessary to do a little prying to get the studs on the felloe-band.

Removing Tire from Demountable Rim.

A rim of the split type must be removed from its wheel before the tire can be removed—or rather, before the rim can be taken out of the tire, which is the actual process.

Lay rim and tire on the floor with the part of the joint that is at the greatest distance from the valve uppermost. Take off or loosen the holding plate or "anchor-plate." Insert a tool under the bead at the end through which the valve does not pass, and press toward the center of the circle, which will spring the rim inward. Move the tool six or eight inches further around and do it again, and continue as often as is necessary. Turn the rim and tire other side up. Insert the tool under both beads at the same time, which will free one end of the rim. Step on the tire to hold it down and pull the rim free all the way around.

Replacing Tire on Demountable Rim.

Partly inflate the tube, but not enough to stretch it, and insert it in the shoe so that it lies smoothly and unwrinkled in its place. Insert

the valve stem in place in the rim, and put both beads of the tire in place at this point. The other end of the rim will rest on the floor with the tire on top of it, neither of the beads in the rim. Work around from the valve, putting the beads in place and leaving the valveless end of the rim to go into place last of all. The inward springing of the rim allows the tire to go on easily.

Getting the ends of the joint together is often the hardest part of the job, and it is here that much damage is done with the hammer. If you lose your temper and bang and whack with the hammer you are fairly sure of getting the joint into bad shape.

This is another job for which special tools are made, and if you have trouble with your rims it would be a good plan to obtain such a tool. And don't forget the graphite compound to prevent sticking.

Taking Care of the Tires.

There is perhaps nothing on the car that pays so well for a little care as the tires, and nothing that will more quickly show the results of improper handling and neglect.

To begin at the beginning, look out for the inflation. There is one correct pressure for a given size tire—and all the others are wrong. You can't judge pressure by a kick. Get a tire gauge. It is an inexpensive thing and worth having. If a tire is under-inflated it will "flex" too much and there will be a tendency for the various plies to work loose. Moreover, an under-inflated tire is more easily punctured, cut and stone-bruised than one fully inflated. If, on the other hand, the tire is pumped up too hard it will be unnecessarily strained and the car will ride hard. Compressed air can make a car ride just as hard as a solid rubber tire, if it is only compressed enough.

The following table gives the correct pressures for tires of various sizes:

Tire Size	Air Pressure
2½ inches	50 pounds
3 inches	60 pounds
3½ inches	70 pounds
4 inches	80 pounds
4½ inches	90 pounds
5 inches	90 pounds

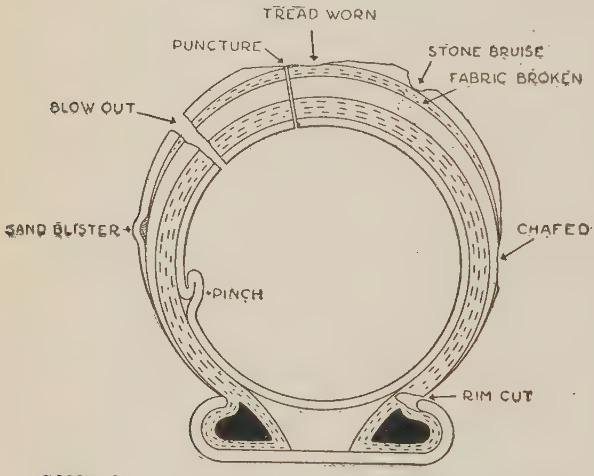
The air pressure increases slightly when driving because of the heat generated. The tires are made to stand this, however, and this factor is taken into consideration in giving the inflation pressures. A tire pumped too hard in the first place is placed under a very severe strain

after it has been driven for some time, and especially if it is driven hard.

Tire Ills and Their Cures.

There are little things that happen to tires on the road that do not interfere immediately with their running, but may, and very often do, develop into greater troubles that lead to the repair shop and thence to the owner's purse.

Stone bruises and cuts are much alike, the difference being that a cut is simply a gash, while in a stone-bruise rubber is gouged out and even the fabric may be broken. Rim-cutting, resulting from running with the tires insufficiently inflated, can easily be avoided. Cuts and stone-bruises sometimes allow sand or dust to work in between the tread and the fabric, causing sand-blisters. A blow-out may carry away part of the tire or it may simply leave a hole. A puncture is simply a small hole and does not involve the cutting away of the rubber, as does a stone-bruise.



SOME OF THE MOST COMMON CAUSES OF TIRE TROUBLE

Fortunately, no one tire will suffer from all these ills at once. Nine-tenths of good or bad tire service rest with the driver.

It pays to mend up all injuries to the tire tread. Materials for filling in stone-bruises and for closing up cuts are easily obtained and it is only necessary to follow carefully directions for using. The cuts and bruises may not be much in themselves, but they often lead to worse things. A puncture may occur where the rubber has been already weakened when it would be warded off if the rubber were all there, and the same is true, in its way, of sand-blisters. If a tire happens to have a weakness on the inside which, however, will not show up until the outside is injured, it may let go and cause a blow-out, thus ruining a tire which might otherwise have been saved.

A cause of blow-outs that is by no means uncommon is the wearing of the walls of tires by allowing them to scrape against curbs. This hits the tire at its weakest point. All that can be said is, "Don't do it."

Repairing Punctures.

A patch put on a tube with ordinary rubber cement can be considered only a temporary repair. It is reasonably sure to let go sooner or later. Patches should be vulcanized on, and vulcanizing is so easy and the tools for doing the work are so inexpensive that there is no good reason for not doing it.

Patches applied without vulcanizing should always be of ample size. Put a 2-inch patch on a hole as big as a lead-pencil. A hole as big as a dime should have a patch three or four inches in diameter. Bigger holes are hard to hold with ordinary patches. Have them repaired by vulcanizing.

An ordinary patch put on without vulcanizing cannot be made to hold its best if simply coated with cement, slapped on and left to dry or put immediately to work. The place where the patch is to be applied should be carefully cleaned with gasoline and then roughened with sandpaper. A coat of cement is put on both patch and tube and allowed to become quite dry. Then a second coat is applied and allowed to become tacky—about half dry—before the patch is put in place. Hold the patch down by means of a clamp while drying or, if on the road and minus a clamp, put on as heavy a weight as is available. A patch put on in this way will do all it is capable of doing, but it is by no means as good as a vulcanized patch.

With the small vulcanizers that are so plentiful it is no more trouble to vulcanize a patch than it is to cement one on and make a good job of it.

In case of a blow-out when there is no spare tire, the only thing to do is to make a temporary repair by putting in a new tube and an inner sleeve between the tube and the damaged part of the shoe, and on the outside a blow-out patch or shoe, which is laced or hooked in place. Thus both outside and inside are braced and protected. Blow-out shoes are made in a great variety of kinds and sizes and there should always be one in the repair kit.

Oil causes rubber to deteriorate rapidly, entirely destroying it as rubber and reducing it, if time is allowed, to a soft, sticky mess. Rubber that has been attacked by oil cannot be restored to its original condition. So keep oil and grease off your tires. Look out for oil on the garage floor. It is pretty obvious that if the car is left with the tires standing on an oily floor nothing but harm can result. See that there is no oil on the garage floor, or at least see that the car stands where there is none.

If a valve leaks persistently the best thing to do is to put in new "insides" which are cheap and easily put in. A slow leak in a valve is an

unmitigated nuisance and need not be tolerated. Keep oil and gasoline away from the valve insides, as they destroy the rubber packing.

A valve is easily and positively tested for a leak by bringing it down to the bottom of the wheel and putting a drop of water in it. If there is a leak bubbles will be formed. Tighten the valve, using the end of the cap, which is formed for that purpose. If this does no good put in new "insides" or core.

What to Do when Tires are Worn.

In time the tread of a tire wears down until, if it is allowed to run long enough, the rubber is all worn off. If the tire is otherwise in fairly good condition it will pay to have it retreaded, after which a good deal of additional mileage can be extracted from it.

Do not let a tire run too long before having it retreaded. If it is allowed to wear down to the fabric it is considerably weakened and, besides, water will rot the fabric and make things worse. The entire tread can be replaced with satisfactory results if the main body of the tire is uninjured except as to normal wear and tear; but retreading a tire that is worn in the fabric is a proceeding that is often of very dubious value.

Conserving Tires by Correct Driving.

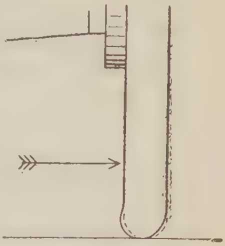
The way a car is driven has much to do with the way the tires stand up and give service. Sudden applications of the brakes are very hard on the tires, especially if the wheels are locked and the tires dragged along the road. On the same principle the action of the clutch should be easy, for starting the car with a jerk tells on the tires. Keep the tires from grinding against the curb, which injures the side walls. Driving in car tracks is bad practice, notwithstanding the fact that it is often done. If you find the car in grooved tracks, or in a rut, get out by giving the wheel a quick turn, and not by gradually forcing the tires over, which grinds them against the rails.

Dodge around stones in the road, and when you have to cross railroad tracks do it at low speed. A sudden blow on the tire is capable of rupturing the fabric and a little later there will probably be a blow-out.

Driving on a flat tire injures the shoe, even if the rim is of a form designed to prevent rim-cutting. Further, it is likely to tear the tube. Don't drive on a flat tire unless you are willing to take a long chance on sacrificing the tire.

Rounding corners at high speed imposes a very heavy strain on tires, and a weak tire subjected to such treatment may blow out. The cen-

trifugal force developed by a car even of moderate weight in making a turn at high speed is tremendous. The side walls, which are not intended to stand such treatment, are unfairly overloaded. Further, the tendency to skid has a tearing effect on the tread and if actual skidding occurs on a dry road the grinding effect is severe. Go easy on the corners.



HIGH SPEED AROUND CORNERS

This exerts a tremendous side strain on the walls of the tire and cannot help but reduce tire life.

When using chains, see that they are loose enough to move about on the tire, so that they will not always rest on the same place; if they do they will cause localized wear. On the other hand, if they are too loose they may kink and cut into the rubber.

The oil used in oiling roads is hard on tires if it is allowed to remain on them. It will pay, after coming in from a run on freshly oiled roads, to wipe off the tires with a rag wet with gasoline. Incidentally, gasoline itself will dissolve rubber if given a chance, but a small quantity dries off before any harm can be done.

The difference in pressure in tires due to difference of atmospheric temperature is so slight as to be negligible, as long as the tire is inflated only to the normal pressure. Do not reduce tire pressure because of hot weather.

When the car is out of service jack it up so that the weight will be taken off the tires. Long standing on the tires is injurious. Leave sufficient air in the tubes so that the tires will retain their normal shape, but do not leave full pressure.

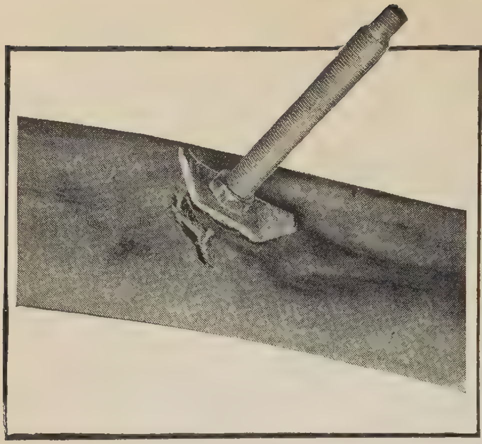
Opinions differ, even among tire makers and dealers, as to how tires should be taken care of if the car is laid up for a long time—all winter, for instance. Some believe that it is sufficient to jack up the wheels and leave the tires on, partly inflated so that they will hold their shape.

There can be no question, however, that the safest way is to take the tires off, clean them carefully inside and out, wrap them in heavy brown paper or burlap and store them away, lying flat and without weight on them, in a dark place moderately heated—not hot and not cold. The rims should be gone over and rust removed with emery cloth or a scratch brush, and a coating of graphite compound put on to keep them in good condition.

Remove the tubes and squeeze all the air out of them after unscrewing the valve "inside." Fold or roll them neatly, dusting them with talc if necessary and put them away in tube boxes or other receptacles.

Tires and tubes must be perfectly dry when put away, and they should be kept in a dry place.

One very good reason for taking the tires off for the winter when



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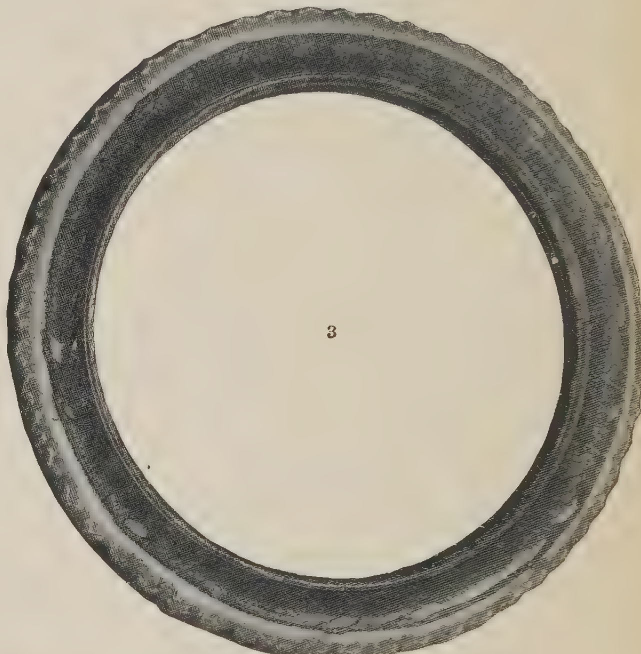

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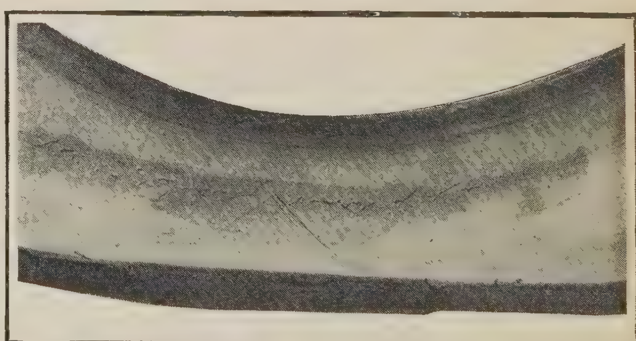

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A FEW TYPES OF TIRE TROUBLES

1.) A tube torn due to crooked valve stem; 2.) see that the valve is straight before the tire is inflated; 3.) driving in ruts and rubbing against the curb are the two most common causes of side wall wear; the rubber is thin at these places and the exposed fabric will soon rot, and later result in a blowout; 4.) the effect of chains applied so tight that they cannot creep; 5.) the interior effect of running a tire deflated.

the car is laid up is that they ought to be taken off anyway to dry them thoroughly and to see that the rims are in such condition that the tires will not be stuck. In any case the tires would have to be taken off in the spring, if the owner cared anything about their condition and that of the rims, and they might, therefore, just as well be left off and wrapped for the hibernating period.

Some tire makers recommend that a new tire intended for use as a spare and carried on the car, should be used for a time until it gets a normal coating of dirt. This is believed to protect the rubber somewhat from the effect of light, which is known to be injurious. Also it has the effect of making the tire somewhat more pliable and more easily handled, should it be necessary to take it off the rim.

Driving over fresh beds of crushed stone is hard on the tires. The best plan, if the distance is short, is to speed up the car enough so that it can be allowed to coast over the stones, for this takes the driving force off and to that extent saves wear and tear. If the stretch is too long for this, drive at a moderate speed—not too slowly, as this will give time for a sharp stone to dig in, and not too fast because it increases the force of impact and the rearward pressure against sharp stones. Driving over stones is an unpleasant and unprofitable business at best.

As a rule it pays to use oversize tires. The first cost is greater, of course, but as a rule the saving effected through longer service is more than enough to offset that, so there is economy in the long run, as well as somewhat easier riding.

Running through deep sand is often a surprise to the inexperienced driver, for the wheels slip and chains are practically useless if the sand is soft and shifty. The car may be stalled, and it is often difficult to extricate it. It will help matters considerably to run with the tires partly deflated, letting out say from a third to half of the pressure. For instance, if the tires are inflated to 60 pounds, bring the pressure down to 40 or even 30 pounds. Be sure to pump up to normal pressure when the sand has been passed. This is an emergency measure to prevent stalling. It is seldom that bad sand stretches are encountered that are long enough to permit any harm to be done by the temporary reduction of air pressure.

While it is by no means unusual to see spare tires carried without covers, exposed to the light and heat of the sun, such a practice can only do harm, and the spare tire should be protected.

The life of a tire is short enough at best, and the expense of keeping a car in tires is sufficient to warrant taking every possible precaution against deterioration. Careful driving, prompt attention to small in-

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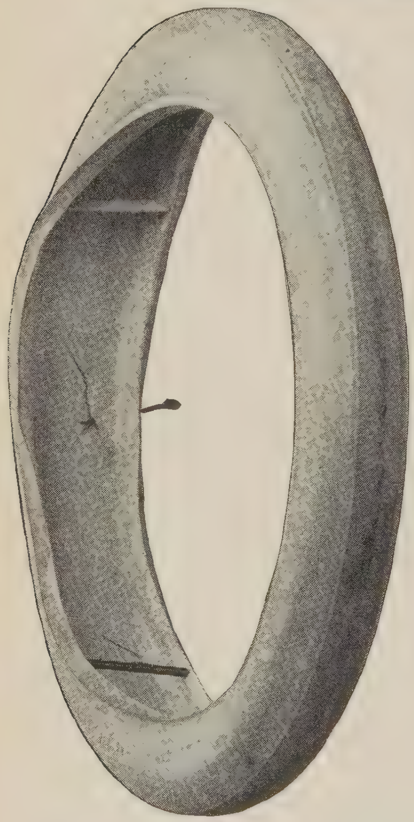

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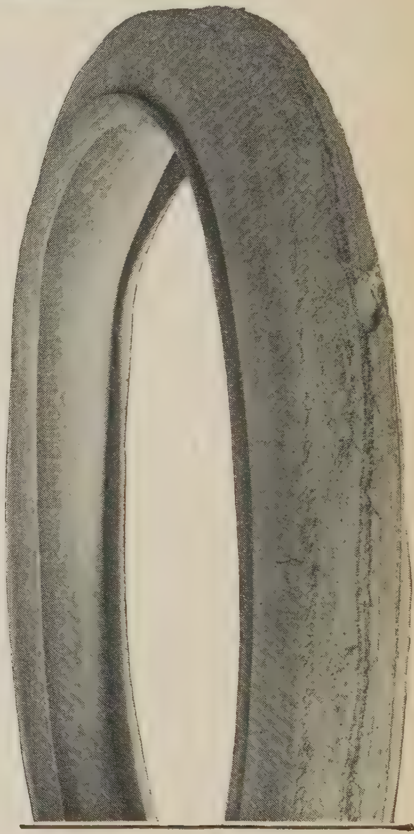

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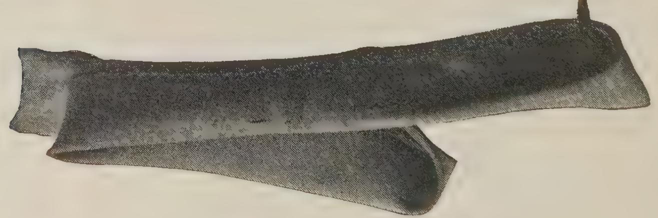

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EASILY-AVOIDED TIRE TROUBLES

1.) Poorly adjusted brakes which cause the wheels to slide will soon wear the tread and fabric; 2.) a long nail may make a cut in the fabric, noticeable only from the interior; 3.) wheels or axles out of line cause continual rubbing which will soon wear the tread through to the fabric; 4.) pinched tubes are caused by careless installation of the tube flap.

juries, observation of the various rules for protecting tires from natural deterioration—all these things add many miles to tire life, and the cost and trouble are more than repaid not only in satisfaction but in actual cash.

WHAT YOU SHOULD KNOW AFTER READING SECTION V

How fabric tires are constructed.
How cord tires are constructed.
What the moulding process is.
What the wrapped tread process is.
How tires are held on the rims.
How the valve is constructed.
How tubes are constructed.
How to use inner tubes of sizes different from the shoe sizes.
What a one-piece clincher rim is.
What a quick-detachable clincher rim is.
What a straight-side detachable rim is.
What a demountable rim is.
What a demountable-detachable rim is.
How a rim is made to take both clincher and straight side tires.
How to take off and put on a clincher tire.
How to avoid pinching the tube.
How to remove a demountable rim.
How to remove a demountable rim from the tire.
How to replace demountable rims and tires.
Why correct tire inflation is important;
What air pressures should be used for tires of various sizes.
How driving increases air pressure.
How to repair small injuries to tires.
How to put on a patch.
What sizes patches should be.
What happens when tire injuries are neglected.
What effect oil has on rubber.
What to do in case a valve leaks.
What to do when the tires are worn.
What car tracks do to tires.
How to turn out of grooved tracks.
What curbs do to tires.
How tires are affected by the use of the brake and the clutch.
What results from driving on a flat tire.
How tires are strained by turning corners at speed.
How to avoid chain wear on tires.
What to do with tires when the car is out of service.
How to drive over crushed stone.
How to drive through sand.
Why it pays to use oversize tires.

SECTION VI. THE BODY, TOP AND UPHOLSTERY

Why the Body Finish Needs Care.

There is no getting away from the fact that the finish of an automobile body is decidedly delicate, and that it cannot be kept looking as it should look without a good deal of care, and intelligent care at that. Paint and varnish are not only easily affected by abrasion, as from particles of dust and grit, but they are marred by many chemicals that cannot always be prevented from reaching the finish. The commonest of all things, mud, is an enemy of the finish both mechanically and chemically. The grit scratches and there often are chemicals in it that dull the varnish. Alkalies in mud often cause trouble, and the mud from roads where there is much horse traffic is particularly bad because of the considerable amount of ammonia it contains.

It is not good for the finish of a car to keep it in a stable or barn where animals are kept because of the ammonia vapors which attack the varnish. Oil and road tar also are bad.

Sometimes the finish of a car is marred from causes inherent in the finish itself, and of course the owner has no control over this. Such troubles naturally are more likely to occur in the cheaper cars, which are necessarily finished somewhat hurriedly and without the long and expensive processes used in high-priced machines. Blisters sometimes result from the application of paint and varnish over previous coats not thoroughly dry. The finish cannot be expected to prove as durable as that of a car that cost a great deal more money. But any finish will inevitably become dull with use.

How to Wash a Car.

Knowing the principles back of a thing so seemingly simple as washing a car helps not a little, just as it does in looking after the mechanical parts of the machine. It is far better to know why you do one thing and avoid doing another than simply to do, or not do, without reason.

If you take a piece of cloth and cover it with dust and rub it over the car body you will expect the paint to scratch and dull. There is no difference, so far as effect is concerned, between doing that and rubbing a cloth over the dusty varnish, and though one such dusting might not make much difference, the end of the season would see a vast dulling in the lustre. It is the same with mud. You could take a wet cloth or

sponge and rub the mud off, but you would inevitably do a lot of scratching.

For this reason it is better to flush off as much as possible of the dirt with a hose and then go over the body with hose and sponge together to take off what cannot be flushed off, using plenty of water and applying the sponge gently. Allow the water to run freely over the sponge to carry away the grit and dirt. Keep the stream of water running on the paint in front of the sponge. Avoid very hot or very cold water, as extremes of temperature are decidedly injurious. This method is recommended by body finishers who know their business.

It is a common practice to use various kinds of soap for body washing. The trouble with this is that many soaps are more or less injurious to the finish, and the quicker they act the more injurious they are likely to be because of their chemical compositions. Soaps that will not do any harm are made, however, and they are more expensive than the other varieties. A good soap to use is castile.

After the car has been washed and, if soap is used, rinsed or flushed to remove all traces of soap, it should be dried with a soft cloth or chamois and then gone over with a good body polish on a clean cloth or chamois. If not properly dried the finish will be dulled.

Grease and oil may be removed from the running gear—that is, wheels, axles and so on—with a little gasoline. The slight dulling effect can be neutralized by polishing with a little linseed oil on a soft cloth.

If mud, oil or tar are allowed to remain on the body the result will be spotting. There will be a spot wherever a gob of mud or oil has remained. The moral is to remove them just as soon as possible, and another very good reason for so doing is that the sooner they are tackled the more easily they are disposed of. A good solvent for most oil and tar is old butter that has become too strong to be palatable. Of course good butter will answer—if you don't mind the expense. Vaseline and kerosene can also be used for this purpose.

For cleaning enameled parts of the car a special solution is recommended by the manufacturer of a high-grade machine. It is cautioned, however, that this will injure varnish, so care must be taken to use it for enamel only. The formula is as follows:

Turpentine	2 quarts
Paraffine oil	½ pint
Oil of citronella	1½ ounces
Oil of cedar	¾ ounce

This is to be used only when the enamel is very dull and will not respond to treatment with ordinary body polish, which should be used in the regular cleaning. Apply with the usual soft cloth and rub perfectly dry with another cloth.

Grease and mud collect in considerable quantities on the under parts of fenders, axles and so on, and may be removed with a suds made by dissolving two pounds of soap in a gallon of water. Rinse thoroughly after using this strong solution.

Do not wash the car in the hot sun. The heat dries the water before it can be removed with the chamois, and the result is a dull, lifeless surface.

Do not use much water pressure in hosing. Use the hose without a nozzle, as this gives good volume without too much pressure. Pressure will drive particles of grit along the varnish and cause innumerable little scratches.

Always take particular pains in the washing of a new car. Paint and varnish require considerable time for thorough seasoning, and the finish of a new car is much more easily injured than after the car has been out of the shop two or three months.

Parts of the car, such as the hood near the exhaust pipe, that are exposed to considerable heat may be expected to deteriorate in finish more rapidly than other parts, and in some cases the heat will blister the paint. This is something that can be avoided only if it is possible to introduce a protection of asbestos or something of the sort.

The less polishing you do on your nickled parts the longer they will last, because the polish necessarily takes off the nickel coating. Frequent rubbing with an oily rag will keep the surfaces bright and polishing will be needed less often. When polishing becomes necessary use a good silver polish.

Do not use brass polish for nickel. It will scratch it and wear it down rapidly.

Interior fittings that are silver-plated in many of the high-grade cars are usually lacquered and therefore must not be polished. When they wear they must be re-plated and lacquered.

Taking Care of the Upholstery.

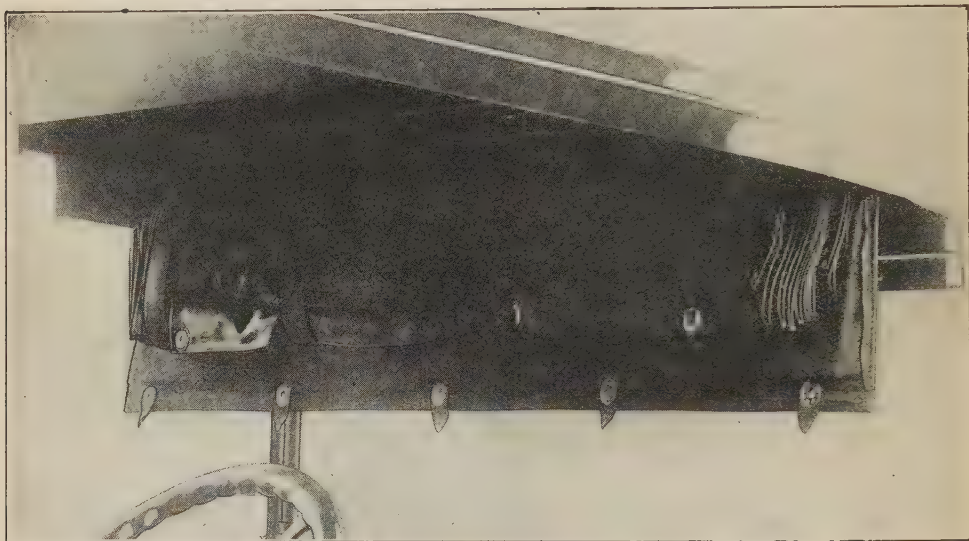
No matter how good the varnish may be, if the upholstery of the car is shabby the whole car acquires a shabby cast. Of course even the best of material is bound to wear in time and to show its wear; but, like the body finish, it can be kept looking well very much longer if it is given proper attention, than if it is neglected.

Neatsfoot oil is an excellent dressing for leather upholstery, and

brightens it a good deal when it begins to show signs of wear, as well as softening and preserving it and preventing cracking. There are various upholstery dressings on the market, some of which are very good. Special preparations are made for leather substitutes or fabric leathers.

Slip covers are very convenient and useful, not only for lengthening the life of the seat coverings but for keeping the coverings clean for "special occasions."

Cloth upholstery should be protected by slip covers for ordinary driving, so that the fabric is kept clean for the aforementioned "special



PROPER CARE OF THE CURTAINS ADDS GREATLY TO THE VALUE OF A CAR

The top should never be folded when wet and the curtains should always be dried out thoroughly before they are stored away. The celluloid windows should not be rolled too tightly.

occasions." Another reason is that grease and other spots are hard to remove without leaving discolorations if they are heavy. This is a job that an expert cleaner should handle. Light spots may be removed with very mild soap and warm—not hot—water and a woolen cloth.

Cloth upholstery should be regularly cleaned of dust by a mild beating process, removing such cushions as can be removed for the purpose, and finishing the job with a whisk-broom.

Care of Tops.

The top is often abused, more through ignorance than anything else, which is the reason that so many tops seem to get shabby quite early in their lives.

A top that is wet from being used in the rain should not be folded

until it is perfectly dry. Leave it standing until it dries out. If it is stowed away and covered while wet, cracking, rotting and mildewing are probable results. It will add considerably to the life of a top if it is always well cleaned before it is folded away.

Don't neglect the top and curtain fastenings. It is altogether too common a thing to see some of such fastenings out of order, and it not only gives the car an unkempt appearance, but may strain some of the parts that should be supported but are not.

Tops made of leather substitutes may be freshened and preserved by the use of the various dressings made for the purpose.

Mohair tops should be given particular attention in the way of removing grease and oil spots, for which purpose a sponge and soapsuds may be used.

Do not use gasoline or kerosene on tops or curtains unless special instructions are given to do so.

Some kinds of artificial leather can be cleaned very satisfactorily with a soft brush and water with a little ammonia added.

Do not leave the top folded if the car is laid up, or it may tend to crack or crease at the folds. For the same reason, it is a good idea to put the top up and let it stay up for a while occasionally if there has been no opportunity to use it.

In folding a top do the job as neatly and smoothly as possible.

Care of Side Curtains.

The much-abused side curtains will give much better service with a little attention.

Before stowing them away wipe them clean with a damp cloth. This not only prevents grit from spoiling the finish, but keeps it away from the celluloid windows, which are easily scratched and, as every one knows, usually are scratched almost to opacity.

If the curtains are marked to show where they go, fold them with the identification marks outside to save time when next they are wanted. Often they are wanted in a hurry, and this practice is worth while.

If the curtains are rolled, do not roll them too tightly or the windows may be cracked. Avoid pressure on the windows that tends to form creases.

Painting the Car.

Any one who cares to tackle the job may paint his own car. It must be said, however, that no amateur or inexperienced hand can expect to produce a job equal to the work of an expert. Even the makers of good colors and varnishes intended for amateur application will not

claim "results equal to expert work" if they are honest—and most of them are.

The first thing to do is to get the car perfectly clean and absolutely free from any trace of oil and grease. If this is not done there will be trouble later on, right up to the last coat.

CURTAINS WHICH OPEN WITH THE DOORS

These are regular equipment on many modern cars. Care should be given to all snaps and fasteners. Curtains should only be unfastened by pulling on the metal—never on the fabric of the curtain itself.

Do not be deluded into believing that rubbing down the old paint with steel wool or sandpaper will get rid of the grease and oil. It won't, in most cases.

When the body and running gear are thoroughly clean go over all the surface with steel wool, which is more convenient and more effective than sandpaper. Sandpaper may be used, however, if steel wool cannot be obtained. No. 00 steel wool is about right.

The point is to get the surface just as smooth as possible. Do not rub through the paint to the bare steel or wood, or there will very likely be a patchy-looking spot there when the job is finished.

Avoid getting an uneven, patchy-looking surface, for color will not always disguise it. If you go deeply into the paint at one place and only touch the surface in an adjoining spot the result will be an uneven appearance.

Remember that high spots, lumps, gouges and deep scratches are very likely to be emphasized in the finished job rather than concealed.

In using steel wool, take a good-sized handful and rub with it until it begins to get "dull," and then turn it over. When there are no more fresh surfaces, pull it apart and fray it out and it will work as sharply as ever. It will gradually wear away as it is used. It is a good idea to wear an old pair of gloves when using steel wool, as the threads of steel have very sharp points and are sure to get more or less painfully into the skin.

After the rubbing-down is finished, get rid of the dust and particles of steel wool that will be everywhere. Do this with the greatest care, for the bits of steel stick tenaciously in corners, to come out at the first touch of the brush and stick to the brush long enough to be transferred to the paint-pot or to the body surface. These particulars of steel make very unsightly spots or lumps, and once the brush and the paint are fouled it is almost impossible to get rid of them.

Dust is about the worst enemy there is in an amateur painting job. It makes the surface speckled and destroys the evenness that is so desirable. It may as well be acknowledged that it is practically impossible to get rid of all dust, which is one of the reasons why an amateur job cannot equal that of a professional. The other reason is that the proper use of the tools and colors requires long experience and training.

Use the prepared paints that are supplied especially for such jobs, and read the directions carefully. As a general rule, it is better to use a paint that requires no varnishing afterward, for varnishing is a good deal of a fine art. A poorly-varnished body is a melancholy spectacle.

Do not put the paint on thickly with the idea of covering the body completely with a single coat. If the old paint was in fair condition, if the rubbing-down was well done and if there is not much difference between the old and the new colors, a single coat may suffice. Otherwise two coats will be needed.

Put the paint on with rather long strokes of the brush, and see that it is well "worked out" so that there will not be thick and thin patches. You can spread the color with horizontal strokes and finish with vertical strokes, which usually gives the best results. However, under no

circumstances finish the first coat with strokes in one direction and the second coat with strokes crossing those of the first. If you do you will get a cross-hatched effect that will not be pleasing.

Be as clean as you can about the job. Keep the handle of the brush clean and carry a rag to wipe daubs of paint off places where they are not wanted. This is easy to do while the paint is fresh, but hard later on.

Try to do your painting on a day when there is no wind, but when the weather is dry and warm. And keep the doors of the garage closed to exclude dust. No matter what you do you will find you cannot entirely eliminate dust, unless conditions are uncommonly favorable. Painters find it necessary to take the most elaborate precautions in this respect, even to building air-tight rooms and supplying them with filtered air.

Don't expect too much of your paint in the way of quick drying, no matter what the makers may say about it. A good paint rarely dries very quickly—which is nothing against it. Avoid touching it until it is thoroughly hard, or permanent marks will result.

If you want to make a good and durable job, let the first coat dry as hard as possible before putting on the second. This makes a lot of difference in the lasting qualities of the finish.

It is a very good plan, especially if there is a good deal of dust in evidence, to go lightly over the first coat with fine steel wool after it is thoroughly dry, thus giving a better surface on which to spread the finishing coat.

If you are putting a very dark color over a very light one, or vice versa, two coats is the least that will answer, and three may be necessary. It is well to repeat the caution—don't try to do the job all at once by laying it on thick. It will come off easily and will not look well.

When the last coat is thoroughly dry give the job a copious washing with cold water. This helps harden the paint and is said to have some effect in preventing its marring so easily while green.

If you want to paint the engine and other parts that get hot, use some of the special colors prepared for the purpose. Ordinary paint is practically useless for this.

Don't put on paint over rust, for it will simply come off a little later. Clean off the rust first, but in doing this, stop just before the metal begins to polish. A slightly rough surface will hold the paint better than a smooth, polished surface in this case.

A dull mat surface can be obtained by rubbing the paint, when hard, with a piece of thick felt and water and powdered pumice. Do not attempt to finish the whole car this way, however, for it is an expert's

job. It is very satisfactory for small surfaces, where you can avoid the unevenness that would show up on large areas.

A steering wheel rim that was once black but has the enamel worn off in spots is a shabby-looking thing, but can be greatly improved. Take off the rim and remove all the old black with steel wool or, if it is very refractory, scrape it off with broken glass or a scraper and finish as smoothly as you can with sandpaper which in this case is more satisfactory than steel wool. Give the rim two or three coats of shellac and rub down the last coat with very fine sandpaper, rubbing very lightly so as not to go down to the wood, which must be covered. Then finish with a good rubbing with linseed oil or, for that matter, any good polish. The main thing is to use lots of elbow-grease and rub hard and long. You can of course put on more black paint if you want, but it will simply wear off again.

Special enamels are made for lamps and other metal fittings. Very often such fittings can be given one coat with no preliminary treatment other than thorough cleaning to get rid of oil and grease. If there is a tendency for the old enamel to flake off, however, the tendency will only be increased when the new paint is put over it, and there is nothing to do but remove the loose stuff and leave a firm foundation for the new finish.

WHAT YOU SHOULD KNOW AFTER READING SECTION VI

Why the body finish needs care.

What mud does to the paint and varnish.

Why a car should not be kept in the same building with horses or cows.

Why the finish may deteriorate through no fault of the owner.

How to wash a car.

Why improper cleaning spoils the finish.

What soap should be used for washing.

How the hose and sponge should be used.

Why mud should be softened before removal.

How to remove grease, oil and tar.

Why a car should be dried after washing.

How it should be dried.

Why a car should not be washed in the hot sun.

Why a new car's finish needs careful handling.

How to make a polish for enameled parts.

How to take care of the upholstery.

How to clean leather upholstery.

How to clean artificial leather upholstery.

How to clean cloth upholstery.

Why slip-covers are desirable.

How to take care of the top.

Why a wet top should not be folded.

How to clean windows in side curtains.

How to paint a car.

How to use steel wool.

How to make a good surface for the paint.

What paints should be used.

How to avoid dust.

How to produce a dull finish.

How to refinish a steering wheel rim.

How to paint lamps and fittings.

SECTION VII. KEEPING THE CAR QUIET

Noises in the Engine.

The amount of noise made by an engine, assuming that it is in first-class condition, depends altogether upon how it is designed and built, and there is almost nothing the owner can do in this respect. Sometimes the cams will clatter on the lifters, due to their design, and sometimes the lifters will click as they come down. The best that can be done is to keep the engine as a whole in the best possible condition and, in particular, see that the bearings are tight and the valve lifters are properly adjusted. These points have been fully covered in Section I.

If there is a hand crank on the engine it very commonly lacks lubrication, and, moving slightly as the car goes over the road, sets up a little squeak that often is hard to locate. On general principles the lubrication of the crank should not be neglected. The crank may be loose and set up a rattle. If so, it may be eliminated, as a rule, if the crank holder can be made tight enough to pull the crank to one side to hold it.

Loose pump bearings and loose couplings will rattle and knock. The remedies are obvious. A squeak in the engine indicates that there is a bearing running dry and wearing fast; locate it at once and see that it gets its proper lubrication.

Hissing, whistling and blowing noises show that gas is escaping. Look over all joints and gaskets and inspect the spark plugs to see if they leak. A little oil put on a joint where there is a leak will tell the story by bubbling. Close the joint by tightening the bolts. If there is considerable leakage past the pistons there may be a hissing noise.

Occasionally the escape of gas under pressure will produce a noise that is very much like a squeak, and this has been known to start a hunt for a dry bearing when there was none. Hold your ear close to places where there may be leaks, and sound will betray its cause if it is a leak and not a squeak.

The carburetor often makes a steady hissing noise that cannot be avoided. It is rarely sufficient to be objectionable, however. In some carburetors with a spring-controlled air valve the valve will rattle on its seat at certain speeds if it is under insufficient spring pressure. This is an abnormal condition, however, and comes under the head of carburetor adjustment.

A fan that runs at high speed will often make a good deal of noise

if there is a break or dent in the edge of one of the blades. Look out for the fan bearings; if they are loose they are apt to rattle. A badly joined fan-belt will sometimes make a slight pounding or slapping noise. If the fan runs very close to anything it may be sufficiently distorted by centrifugal force when running fast to make contact and produce noise. Inspection will reveal a scraped place where contact occurs.

Noises from the Hood.

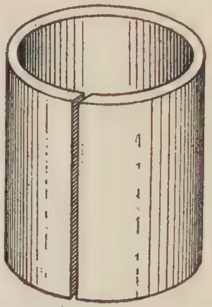
The hood is rather a prolific source of little jerky squeaks that are hard to locate because they occur when the car is running on the road but not when standing. Usually these occur where the hood rests on the radiator and the forward end of the cowl. If they cannot be eliminated by tightening the fastenings, line the edges of the hood on the inside, where they rest on the radiator and cowl, with thin tape or strips of cotton cloth, using shellac as glue. This will usually do the trick and will last for some time. After the lining is on give it a coat of shellac, and while the shellac is tacky rub dry graphite into it, getting as much graphite as possible into the shellac. The graphite will act as a lubricant and will prevent the shellac from sticking when it warms up. Only thin material can be used, as a rule, because thick stuff would spoil the appearance of the joined places.

Headlight and other lamp doors sometimes rattle because the fastenings are not sufficiently tight, and also there will be a rattle if the bracket fastenings are loose. Some reflectors are so attached that their screws can loosen and allow rattling which, however, is not often loud enough to be heard. But just the same the reflectors should be inspected occasionally to make sure they are firmly held. The license plates also may rattle if not screwed up tight.

Rattles in the Steering Gear.

Most parts of the steering gear likely to cause rattling can be adjusted, and a properly adjusted gear will not, or at least should not, rattle; good lubrication is a factor in this. The spark and throttle levers may become loose on their respective sectors from long use and rattle against them on the road. Before this can occur, however, they should have been tightened simply to make sure that they will stay where they are put. In some cars the steering wheel post wears loose in its bearing at the top of the supporting tube. Depending upon the type of steering gear used, this may be remedied by adjusting the thrust bearings or by inserting a new bushing at the top of the column. Such trouble is not likely to occur for a long time if lubrication is properly attended to.

If a new bushing cannot be obtained it is sometimes possible to tighten up the old one so that it will do very well for a time at least. Take out the bushing and split it lengthwise with a hacksaw. Put it back with a liner of very thin sheet brass or copper back of it, so as to close it up on the steering wheel post. The greater the wear the thicker the sheet metal will have to be, and you will have to use your own judgment and perhaps do a little experimenting to get the right fit. Anyway, get a new bushing as soon as possible.



RENEWING A BUSHING

This will temporarily take up the wear and lost motion in the steering connections.

Rattles in the Brake System.

The brake gear is responsible for a good deal of rattling, most of which can be eliminated by ordinary adjustment and lubrication. Joints that cannot be adjusted can be somewhat quieted by using heavy grease instead of light grease or oil. This is but a temporary relief, however, and a better plan will be described later.

Adjustable pedals may work loose and rattle. If, when the pedal is released, it does not rest firmly against its stop, of whatever type that may be, it is almost sure to rattle. If there is no way of increasing the spring tension to give a firmer contact, or if the spring is as tight as it should be, a little pad of leather will stop the noise. Under such conditions leather will wear longer than rubber.

Where there are adjustable bearings, as there may be for the cross shafts carrying the brake pedals, adjustment is easily made and in any case such bearings are large and wear slowly, with ordinary attention to lubrication, and the spring pressure tends to keep them tight.

A rod end is connected to the part which it moves, or from which it takes motion, by some pin-end-eye arrangement, such as a clevis. A clevis is simply a fork on one member, the arms taking between them the flattened end of the other member and a pin passing through holes in both. This kind of a joint wears rather rapidly if the pin is not large, and as it usually is exposed dust and grit do much to hasten deterioration. The wear is nearly all fore-and-aft so that the holes and pins both wear oblong.

When this occurs the holes should be reamed or drilled—preferably reamed—enough larger so they will be truly round and clean. Then new pins must be fitted. Sometimes pins can be obtained of the proper size at a hardware store; they are made in a variety of sizes with heads. If the proper length cannot be obtained, use longer pins, drill for split-

pins and cut off. Another way is to use standard S. A. E. bolts, which are of good steel and accurately finished and can be obtained in a wide range of sizes at large hardware stores. If such bolts are used, care must be taken that the nuts do not screw up tight enough to pinch the joints and spring them out of shape or cause binding. If bolts can be obtained with threads of just the right length so the nut will tighten at the foot of the thread, so much the better. Drill for a split-pin to prevent the nut from coming off. Perhaps the best way is to drill through both nut and bolt when the nut is in its proper position and pass a split-pin through. If the thread is a little too long use this method for keeping the nut where it belongs. In no case should the thread extend more than a very little into the hole in the clevis, for this will reduce the bearing area and hasten wear.

If neither pins nor finished bolts can be obtained do not use unfinished bolts, for they will wear very fast because of their rough surfaces and poor fitting. Use short lengths of plain steel. Finished tool steel is usually easily obtained in any size. A very good head can be made of a nut the hole in which is a little smaller than the diameter of the pin. File or drill out the threads, or at least partly clean them out; the nut must still be a little smaller inside than the pin. Then file or grind the end of the pin till the nut can be driven on, leaving a shoulder for the nut to rest on. Leave the end of the pin projecting about a sixteenth of an inch beyond the nut and rivet it over with the ball end of a machinist's hammer, and finish by filing or grinding up the riveted end to make it clean and shipshape. At the other end drill for a split-pin, leaving enough room for a washer between the split-pin and the clevis. Use a good stout split-pin in this case and do not forget the washer. Have the washer a snug fit on the pin to avoid its little rattle.

MAKING A PIN

This may be used to eliminate the noises in the brake rods.

If an external brake band is too loose—too far from the drum—it may possibly rattle against the inside of its housing. In some brakes, especially in the cheaper cars, a certain amount of wear will allow enough side play for the band to rattle against one side or the other of the housing. These things are simply matters of ordinary adjustment. As a rule the springs in the brake operating mechanism keep the joints of the toggles from rattling.

Noises in the Gearset.

Gears are bound to become noisy when they wear, and the real remedy is a new set of gears. This is of course somewhat expensive. There are "dopes" made for quieting noisy gears, composed of grease

of some kind mixed with ground cork, cedar sawdust or some such substance. In some cases this gives very good results. The solid matter has a marked cushioning effect and under proper conditions will often enable the car to run quietly on old gears for several seasons.

In using such dope it is necessary to use some care. Some of the compounds have a tendency to lump up due to the partial separation of the solid matter as the lubricant thickens up in service. The gearbox should be opened up occasionally and the dope examined, and if it seems to be lumping and thickening, take it out and add fresh. Do not use this quieting dope in a gearset designed to be lubricated with oil without finding out from the manufacturer or the service station if it will work without doing harm. However, it may be said that most manufacturers object to lubricants of this kind, though users in many cases have obtained good results.

Knocking Universals.

Universal joints wear and develop knocks that are very annoying, and the remedy is almost invariably the insertion of new bushings for the trunnion pins, as has been pointed out in Section 3, Chapter 3.

Torque Tube Rattle.

The jointed end of the torque tube wears and produces a rattle in some cars and its noise changes with the various driving conditions, usually being most pronounced when coasting because there is no pressure to keep it tight. Often the pivot pins are run through bushings, and when this is the case the installation of new bushings and pins will restore the joint to its original tightness. When there are no bushings the holes must be reamed out and new and slightly larger pins used. As these joints are of considerable size, the job is one that should be done by the repairman. In some cases means of adjustment are provided.

It may be pointed out that the torque tube joint is generally provided with means for lubrication which are commonly neglected because somewhat hard to get at. Never mind that. See that the lubrication is supplied and that it gets where it is needed.

The same remarks apply to radius rods, where these are used instead of a torque tube.

Spring Noises.

Spring noises are squeaks and creaks due to lack of lubrication between the leaves and rattles due to looseness of the bolts in the eyes

and brackets. The remedies for these troubles have been thoroughly covered in Section 3, Chapter 4 on Springs.

Synchronous Vibration.

Everything that can be made to vibrate has what is called its own "moment of vibration." That is, it will vibrate naturally, if the impulse is provided, at so many movements per second, depending upon its elasticity, weight and dimensions. A pendulum is a good example. Start it swinging, and it will require only a slight impulse to keep it going at its natural rate of swing. The shorter it is the faster it will vibrate. So it comes that many parts of the car will set up their individual vibrations when the engine reaches such a speed that its vibration has the same period—in scientific language, when the periods of vibration are synchronous or agree in time.

If a brake rod, for instance, has a period of ten vibrations a second, it will start vibration when the engine reaches a speed that produces a vibration of ten to the second. Below or beyond that it will not vibrate. At lower or higher speed the engine vibration may synchronize with that of some other part, which will lift up its metallic voice if there is any looseness. Gears that do not run smoothly will set up vibrations that may synchronize with the periods of parts and cause mysterious noises. Some cars have been unable to use certain forms of universal joints because the gears started them vibrating in this way. Gasoline and oil pipes, rods, levers—almost everything on the car can be made to vibrate in synchronism with the vibration of the engine or of the car as a whole. This explains why when running over a road paved with cobblestones at a certain speed some parts will set up a rattle that is not in evidence on an ordinary rough road and that will vanish at a different speed over the same cobblestones. Once synchronous vibration is started it requires very little to keep it going —just the slightest impulse, as in the case of the pendulum.

Consider this matter when going over the car for rattles, and see that all parts that should be tight are tight. Long pipes should be secured to something to prevent vibration. A long pipe—that is, a length of pipe with considerable distance between supports—will have a slow period of vibration and will be easily started going. Fasten it at the middle of its length and the period of the two half-lengths still unsupported will be just twice as high as that of the whole length, and probably so high that their periods will not be reached at any speed.

Lamps often are subject to vibration of this kind when supported on pillars or high brackets and may rattle considerably. The trouble

can usually be cured by moving the lamps lower down on the pillars, which has the effect of raising the period of vibration because, as has been pointed out, the shorter the object the higher its period of vibration, other things being equal.

Rods through which the carbureter, ignition and so on are controlled may vibrate and be a little noisy if there is looseness. Look out for the muffler supports and for the connections of the exhaust pipe. The impulses from the exhaust sometimes start vibration here if there is a chance for it.

Shock Absorber Noises.

Shock absorbers, auxiliary springs and like devices are subject to very severe vibration and though usually held tight by spring pressure or weight or both, may develop rattles and, in the absence of lubrication, squeaking. Rattling of course means simply that there is looseness to be taken up somewhere, and just where will depend upon just what device is used—and there are scores of them. Sometime a spring, and especially a coiled spring, will emit a creak every time it moves, though there apparently is nothing to cause friction. The cause will usually be found in the rubbing of the end or base of the spring in its seat, and a heavy graphite grease will stop it. The springs of the car will sometimes creak in the same way on their perches if the clips or U-bolts are not tight.

Body Noises.

Of all the noises the car makes those produced in the body are the most annoyingly difficult to locate and stop. Many good cars are fitted with felt strips at points and joints where noise may occur, and in such cars body noises are practically eliminated. An old body gets loosened up and creaks and squeaks badly in some cases.

The principle of the thing is that wherever there is a noise there must be movement to produce it, and to stop the noise the movement must be stopped, or at least something in the way of padding or lubrication used to eliminate sound. Go over every bolt, nut and screw of a noisy body and see that they are as tight as possible. Where a noise can be traced to its source—which is often very difficult because such noises have a trick of hiding when they are looked for—a remedy can usually be devised, the nature of which will depend upon the character of the source. But noises that come from the working of joints in wood frames loosened up through long service are hard to do anything with, unless the tightening of fastenings will help.

Doors that rattle can nearly always be fitted with some form of anti-rattling device, of which there are many on the market. Fenders will rattle badly if their supports are loose.

If there is a box or compartment on the car into which you are in the habit of chucking loose tools and "junk," do not overlook it in quieting your car. Put the tools in a roll, or wrap them in cloth or something to keep them quiet. An untidy tool-box may make a car sound like a boiler-shop on a rough road.

WHAT YOU SHOULD KNOW AFTER READING SECTION VII

What noises occur in the power plant, and how to prevent or remedy them.

How to stop squeaks and rattles in the hood.

Why lamps rattle.

How to stop steering gear rattles.

How to take up wear in a steering post bushing temporarily.

How to cure rattles in the steering gear.

How to make a worn clevis joint tight.

How to make pins for a clevis.

How to silence noisy gears.

How to silence universal joints.

How to silence a torque tube or radius rod.

What spring noises are and how to stop them.

What synchronous vibration is.

How synchronous vibration causes rattling.

How to prevent synchronous vibration.

Why a car rattles on cobblestones and not on a rougher road.

How lamp position affects vibration.

How to stop noises in shock absorbers and auxiliary springs.

How to stop rattling doors.

What to do when the body rattles and squeaks.

SECTION VIII. THE PRIVATE GARAGE

Planning the Garage.

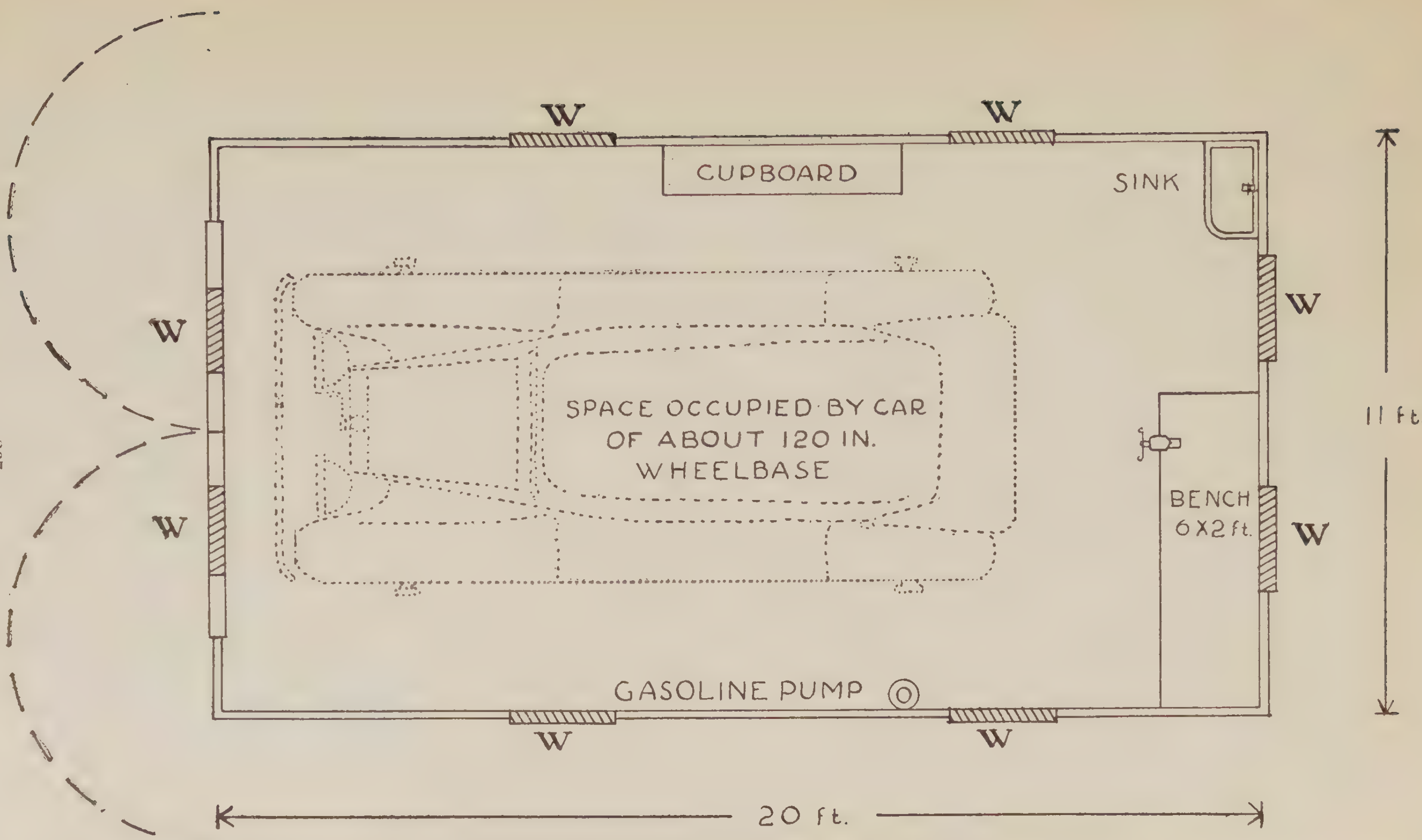
The plan of the private garage must of course depend upon the individual requirements of the owner—the space needed, the ground area at his disposal, the amount of money he wants to put into it, and so on. There are, however, many considerations that apply to the garage no matter whether it is big or little, expensive or cheap.

In the first place, it is a mistake to build the garage so small that there is just room to get the car in and let the driver squirm his way out between the car and the wall—so short that the car almost touches one end in order to allow the doors to be closed.

Every car will accumulate around itself a number of things that require more or less storage space, and if they are not provided for the owner will always wish he had built a little bigger. There should be room for a small work bench and enough room before the bench to work comfortably. There should be room enough around the car not only to move around with freedom, but to use levers if necessary in handling heavy parts. A foot or so added to the garage does not make a very great difference in the cost, but it does make a very great difference in its actual value.

One of the commonest mistakes made in building small garages is to skimp on the windows. Seldom are there enough of them to give the light that is needed, and most garages are so dark in gloomy days that it is difficult to see well enough to do good work without artificial light. Use plenty of glass. In good weather you can work with the big doors open, but even this does not altogether fill the bill when you are working at the opposite end of the garage with your face toward the light. Have the windows so arranged that they can easily be opened wide so that there may be a free circulation of air and plenty of escape for gases and smoke when you are running the engine. A small garage fills up with gases in no time, and, as is pretty well known, inhaling the exhaust is a dangerous thing and may, in extreme cases, easily cause death.

If, however, the garage is already poorly ventilated, or if it is placed under the house where its air is limited, a flexible rubber hose of the type used in the thermo-syphon cooling system may be attached to the exhaust pipe to lead the fumes out of the window. In this case, a spe-



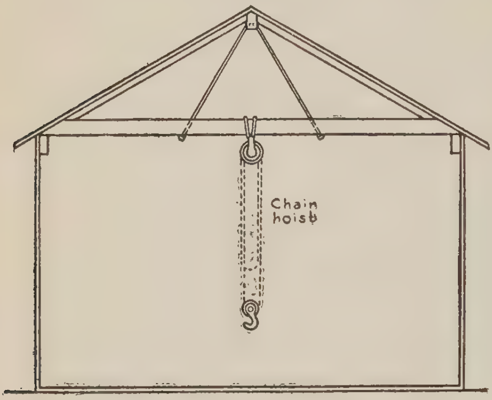
FLOOR PLAN OF A WELL DESIGNED SMALL GARAGE

Make sure that there is plenty of window space, that the doors open to sufficient width, and that the floor is well drained or provided with a drip pan or other means of disposing of the grease and oil. A gasoline storage tank and pump form a valuable addition to garage equipment.

cial clamp may be provided to hold the hose firmly in place on the exhaust pipe, and a hole can be cut in a board which will just fit the window opening when it is raised for this purpose. This hole should be of a size to accommodate the other end of the rubber hose. The window can then be closed so that none of the fumes can blow back into the garage and the exhaust can be forced out of doors. The cost of the necessary 8 or 10 feet of rubber hose may seem rather high but it will be much cheaper than the danger of total or partial asphyxiation.

Arrange for Lifting Tackle.

Have at least two good heavy timbers put across high enough to clear the top when it is raised. These are useful for rigging tackle for hoisting out the engine or the gearbox, and without something of the sort it is necessary to go to a good deal of trouble. If the garage is big enough it is a good idea to have a timber strong enough to permit hoisting the front end of the car clear of the floor to facilitate getting under it. This is in some ways better than a pit, and certainly is cheaper, when the cementing and draining of the pit are taken into consideration.



INSTALLING A CHAIN HOIST
The cross timbers may need to be supported but any such expense is well worth while if engine repairs are to be made by the owner.

Many garages may not be provided with sufficient head-room, or heavy enough ceiling timbers to enable the front or rear of the car to be raised from the floor by tackle. In such an event, a jack may be used to furnish more space under the car, or a small, heavily-constructed incline may be built of timbers on which a car may be run under its own power. No matter what system may be employed, however, as long as a pit is unavailable, a creeper is a very necessary part of every completely-equipped garage. This consists of a small wire or wooden cradle mounted on castors and provided with a head-rest. It is built of sufficient strength to accommodate a workman or the owner when he lies flat on his back, and may be moved about on the floor of the garage. A special brake is provided on some types of creepers which lifts the castors off of the floor so that when the desired position is reached, a stubborn nut or other work requiring the exertion of strength will not move the creeper out of position.

For hoisting purposes of this kind there is nothing better than a good chain hoist. Such a hoist is easily handled and it has the great advantage that when the load is raised it is automatically and safely held just where it is left. Moreover, it is easy to move the load accurately, which is a matter of no small importance in getting the engine into place, for instance.

Good Flooring Necessary.

There is nothing better for the floor than concrete. Wood is often used, but it soaks up oil and gets exceedingly dirty, smelly and very combustible. A concrete floor can be kept clean and is, of course, fireproof.

Sometimes small garage floors are laid with the center, under the car, depressed about an inch, forming a permanent pan which may be filled with sawdust to absorb dripping oil. A regular pan may be used, and helps keep the floor clean.

Make the Doors Big.

It pays to have the doors a little bigger than just big enough to let the car in. Especially is this true if the garage is so located that the car has to turn sharply when going in from the approach. This condition often obtains where a garage is built in a small back yard. With plenty of door space it will not be necessary to steer quite so "fine" and there will be less danger of damaging the car when going in or out. Besides, big doors are most agreeable in warm weather, and they help in lighting up on dark days.

Have a Good Bench.

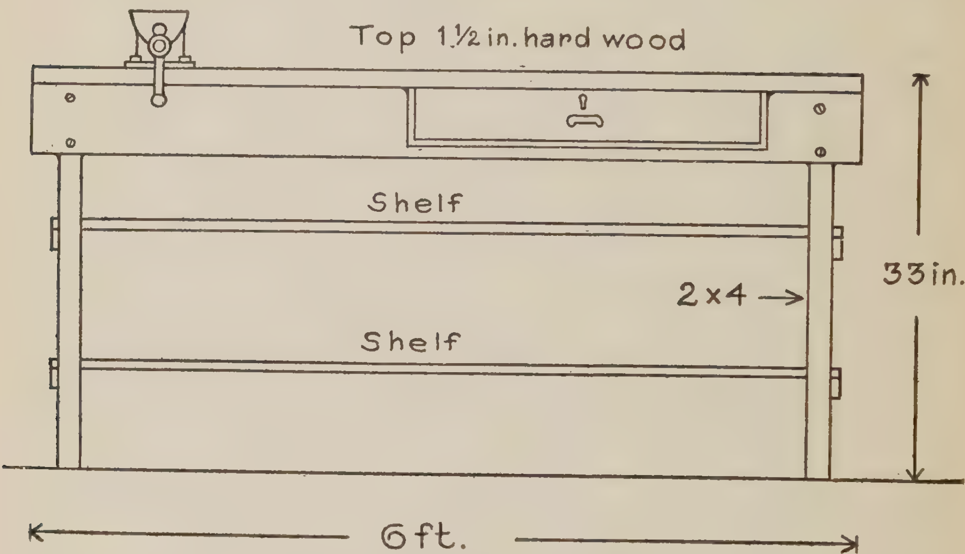
If you intend to do any work at all on your car a good heavy bench is an absolute necessity. A flimsy, light bench is a nuisance. It need not be very big. Five or six feet long and two feet wide is ample. This width may seem to be a little on the generous side, but after a little experience it will be found so convenient and useful that it will be worth the space it takes.

The bench should have a top of hardwood at least an inch and a half thick, and well braced legs of 2 x 4 scantling or its equivalent. Have a good machinist's vise with, say, 3½-inch jaws, and if it is a swivel vise so much the better, for it is a great help sometimes to be able to swing the vise around to get the work into a convenient position. There are many jobs that are very difficult to do without a good heavy vise, but comparatively easy with it. It has already been explained how it may be used as a press. For instance, there is riveting brake lining in

place. The vise is used to hold the iron on which the end of the rivet is set, and it is the most convenient way to do the work.

A small clamp vise, such as can be bought for about two dollars, is practically indispensable for small work. This can be moved about to any part of the bench and clamped to the edge where it can most conveniently be used. It is much better for holding very small work than the bigger tool.

The big vise is best placed near one end of the bench, and it should be directly over a leg to give it solidity—a point that will be greatly appreciated in work that calls for hammering.



A WELL-DESIGNED WORK BENCH

Inasmuch as heavy work will be done on this, the bench itself cannot be made too substantial or heavy. It should be thoroughly anchored to the floor and the more drawers and shelf space available, the more valuable supplement will this become.

Tool Equipment.

The tool equipment required depends so much upon the individual circumstances that it is hard to lay down any rules. If you know enough about mechanical work to go rather extensively into the repairing and overhauling of your car you will not need to be told what to supply.

In any case, one of the first requisites is a collection of wrenches that will fit every nut and screw-head on the car. For real work there is nothing like a solid wrench—that is, a wrench that is not adjustable. A monkey-wrench is a good thing for occasional use, or for carrying in the car to save the space that a collection of wrenches would occupy, and so on. But for regular work nothing beats the solid wrench. And

it may be said that of all unsatisfactory tools a cheap wrench is the worst. There never yet was a wrench that was not over-worked, and if it is not well made of good steel it will get all out of shape at the outer ends of the jaws and round off the facets of the nuts when pressure is put on, or the jaws will break off before they have time to wear down. Buy good wrenches and take care of them.

A hand-drill with a two-speed gear and a chuck that will take drills up to three-eighths of an inch is valuable. Keep your set of drills intact. Drills from an eighth downward are rather easily broken, and it is a good plan to keep two or three of each size on hand. Larger sizes can be used a long time, with care, without breaking.

A hack-saw is another necessity. The eight-inch size is perhaps the most convenient. Buy your blades by the dozen. They are a good deal cheaper that way, and you will break blades faster than you will wear them out unless you are something of a mechanic. Blades are made with fine and coarse teeth. For most work the fine teeth are best. A saw with coarse teeth does not work well in thin metal, and for cutting tubing fine teeth are infinitely the best. Strain the blades good and tight and they will break less easily than if left slack.

Have a good set of screwdrivers of different sizes so that you will always have one of the right size for each screw. Nothing is harder on a screwdriver than trying to make a small tool do the work of a larger one. The tip of the blade is twisted at the corners and worn down. A screwdriver that fits fairly closely into the slot of a screw will last a very long time without showing undue wear.

It is a good plan to grind the point of a screwdriver crosswise so that the grinding marks lie parallel with the edge. This may seem a small thing, but it actually helps the tool to hold in the slot and prevents slipping.

GRINDING A SCREW-DRIVER

If the grinder marks are parallel with the point, a better grip on the screw can be secured.

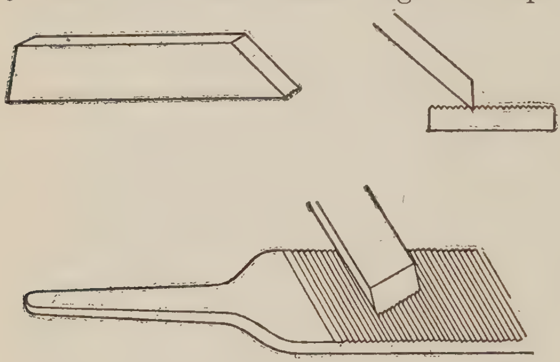
For very heavy work there is a most useful type of screwdriver with the handle made in two parts and jointed where it joins the handle. When a very big and tight screw is to be moved the handle can be set so that one part of it is at right angles to the length of the tool while the other part is vertical. By applying pressure to the part at right angles tremendous leverage is given. If necessary both parts of the handle can be turned down on opposite sides, forming a big T and doubling the leverage.

A good set of files is one of the prime necessities. These will range from the little jeweler's file used for dressing contact points of the ignition system to a 14-inch or 16-inch coarse file for ripping off metal

in quantities. Include in the list a small rat-tail or round file about quarter of an inch largest diameter and a larger round file about half an inch largest diameter, an 8-inch and 10-inch smooth-cut flat file, an 8-inch and 10-inch medium-cut half round file and an 8-inch three-cornered file. With this equipment you will not be easily stuck on any ordinary job.

In using files there is a great deal that can be done to economize in wear and tear. Never use a new file on soft metals, such as babbitt. Use old half-worn files, and rub the teeth with chalk before using, which helps prevent clogging. When filing copper, wrought iron or soft steel use chalk.

If a file becomes clogged in use take a piece of soft wood and cut it to the form of an obtuse wedge. Scrape the edge of the wedge across the file, in the direction in which the teeth run, and the wood will become serrated, fitting into the teeth and cleaning them out. The whole file can be cleaned in this way in a minute or two.



CLEANING A FILE

Chalk rubbed over the file will prevent clogging with particles of soft metal such as copper, wrought iron or soft steel. A clogged file may be cleaned by means of a sharpened piece of wood. A file that is clogged will not cut steel.

In filing do not pass the greasy hand over the work, or the file will at first slip over and refuse to bite until the grease has been scraped off. This is especially true of cast iron. Incidentally, the outer skin of a casting is usually extremely hard and takes a great deal out of a file. If you have to file such a casting break the skin with an old file, using, perhaps, the edges to scrape down to the softer metal under the surface.

Have a good handle for every file. You can't do good work with a handleless file.

It is worth knowing that a file can be magnetized by winding the cord of a lamp around it several turns and turning on the current. Such a magnet has sufficient strength to lift small pieces of metal that may have dropped into inaccessible places—screws or nuts, for instance.

If you have a great deal of metal to remove from a large piece, a good file to use is a 16-inch square file—not flat. This rips it off in short order. Even better, if more expensive so far as first cost is concerned, is the type of file in which the teeth are formed like the

teeth of milling cutters on a small scale. These files cut very fast and clean and are extremely good tools.

For filing work where the file must be used close to a projection that must not be cut use a file with a "safe edge," which is simply an edge with no teeth on it.

A file cuts only when moving forward. So when drawing it back for a new stroke, put no pressure, or only the very lightest pressure, on it. This helps a good deal in saving wear. Pressure applied on the back stroke does no good whatever.

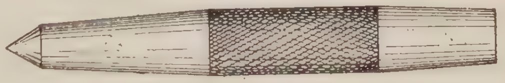
In filing sheet metal put it in the vise with the edge to be worked on as close as possible to the jaws, and work the file along the length of the sheet, or diagonally across, rather than at right angles. You will thus eliminate the fearful screeching and at the same time cut a good deal faster.

For filing small pieces that cannot conveniently be held in the bench vise a small hand vise is useful. This grips the piece and at the same time forms a handle by which it may be held in the left hand while the file is used with the right.

Don't bang the file against the vise to knock particles of metal out of the teeth. It is bad for the vise and worse for the file. Knock it against the edge of the bench. A rub or two with a piece of wood is better, however.

Keep your old files. There is good steel in them, and odd tools, such as scrapers, punches and cold chisels can be made from them by grinding or by softening and filing. Soften a file by heating it all over to a moderately bright red and leaving it buried in the ashes, or better yet in slacked lime, until cold.

A very nice center-punch can be made from a piece of an old round file by grinding it tapering at one end to form a head and at the other for the point, leaving the teeth on the shank to give a good grip. If the steel has first been softened the point must be hardened and tempered—two different operations. To harden, heat about an inch of the point to a moderate red and dip it vertically into cold water. This makes the steel extremely hard—so hard and brittle that it would shatter at the first blow of the hammer. To temper this hardness, clean the steel at the point so that it is bright and polished, with sandpaper or emery or a scrap of sandstone. Apply heat a couple of inches back of the point and watch. You will see the color of the metal change and the changes will run along toward the point.



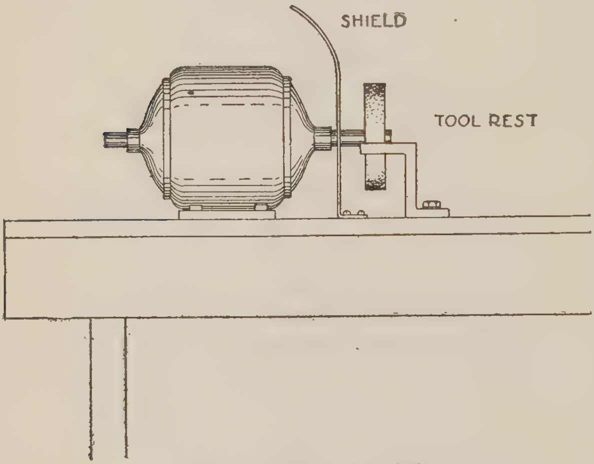
HOW TO MAKE A PUNCH

The steel of which files are made is well-adapted to heat treatment so that a punch having an exceedingly hard or tough point may be made easily.

When the point reaches a medium straw-color put the tool quickly in water, and it will be hard enough for work but not so hard as to be brittle. The same process can be used for making and tempering cold chisels and the like.

Another way of tempering is to heat the tool for perhaps half its length and quench in water only about two-thirds of the heated part. Then take the tool out of the water, polish the hardened end very quickly and watch for color. The heat still remaining higher up on the shank will travel to the point and temper it just as in the previous case. This is perhaps the easiest way when one has had a little practice, but it must be done a little more quickly than the first described way.

Half a dozen cold chisels make a good set—two flat chisels, one large and one small, two round-nosed chisels and two narrow-bladed "cape" chisels. With these you will be well fixed.



A BENCH EMERY GRINDER

This is one of the most useful tools in a garage. An old electric motor can be installed easily at a small expense, if electric light current is available.

Some sort of grinder for sharpening tools should be at hand, and it is such a useful appliance that it is worth more than it costs. About the most thoroughly satisfactory thing for all-round work is an ordinary good-sized grindstone with foot-power, though there are many small grinders operated by hand that are good. The trouble with the hand grinder is that one does not have both hands free to hold the tool, which is a good deal of a handicap. If you use a grindstone, never use it dry, and don't persist in using the middle of the surface for work. Spread the wear all over and the stone will remain in condition a great deal longer. If you have an old electric fan motor a small emery wheel can be mounted on the shaft and used for light grinding, and this is an ideal arrangement. It is advisable, however, to make a shield of light sheet metal to protect the motor from the dust of the wheel. Fasten the motor to the bench with the shaft running through a hole in a good-sized sheet of tin or sheet iron standing upright; the lower edge of the tin can be bent to form a foot which can be screwed to the bench.

Artificial Lighting.

Have plenty of artificial light. Over the bench there should be a lamp with some kind of flexible or adjustable arm so the light can be thrown on the work in the vise or on the bench to the best advantage. Have also a guarded lamp with a long cable of the kind used in big garages—heavily insulated cable that will stand the rough usage it is sure to get. Have the cable long enough so it will reach any part of the car. Use a half-shade on the lamp so the light will all be thrown on the work and not in your eyes. Also use a hook on the frame so that it can be hung any place near the work.

Water Connections.

It saves a great deal of bother to have water run to the garage. If this is done, have a small iron sink with drain pipe put under the tap, leaving plenty of room to get a big pail under the tap. Have a tap with hose connection so water can be led direct to the radiator, as well as being available for washing the car and for flushing the garage floor occasionally.

Storage for Cans.

Have a regular metal oil cabinet if you can. If you can't, at least have a cupboard in which your oil and other cans can be kept.

Of course the ideal arrangement for handling gasoline is the underground tank and pump system. If you are going to install such a system the makers of such appliances will give you all the information you want and will tell you how to make the installation so that it will meet with the approval of your local insurance people—which is something of great importance. There are many kinds of gasoline systems, and you will have no trouble in selecting one that will fill your requirements. One important consideration is to have the pump where it will be convenient to the tank of the car, and another is to have the storage tank filler convenient of access for the tank-wagon.

Fire Precautions.

You should have means for extinguishing possible fires, and there is nothing better than fire extinguishers of the chemical type made for the purpose. Water is of no use in case of a gasoline or oil fire. Sand is good, but it is terrible stuff to get into the working parts of the car, though it is very effective for burning gasoline on the floor. Wet sawdust is also good, though the trouble is that it must be kept wet. The most important thing of all is to be careful not to let a fire start—the usual ounce of prevention.

WHAT YOU SHOULD KNOW AFTER READING SECTION VIII

How to plan a private garage.

Why it does not pay to economize space too much.

Why plenty of window space is important.

Why ventilation is essential.

How to arrange for lifting tackle.

How to get under the car without a pit.

What kind of a floor to use.

Why big doors are desirable.

How to build the bench.

What kind of a vise to use.

What tools to provide.

How to keep the tools sharp.

How to make tools from old files.

How to harden and temper tools.

How to get the most out of screwdrivers and wrenches.

How to get the most out of files.

How to make a magnet of a file.

How to clean files.

How to make a power bench grinder.

How to arrange artificial lighting.

How to have water connections installed.

How to have the gasoline supply installed.

What to do with cans.

How to take precautions against fire.

SECTION IX. HOW TO JUDGE A SECOND-HAND CAR

This is the era of the second, third and even fourth-hand car. The manufacturers of new cars are unable to supply the demand, and the prospective purchaser is forced to content himself with a car which may have served the purpose of two or three previous owners.

"Trades" are common, and many an owner of an erstwhile good car sells it or turns it in as partial payment for a better one, which, also, may have seen considerable service.

Covering Up the Faults.

It is almost as difficult to judge of the actual condition of a second-hand car from a cursory examination as it is to determine the character and mental attitude of a man upon first acquaintance. The psychological moment must arrive before a man may exhibit the best or the worst that is in him. So it is with a car. The use of a heavy grease with which cedar sawdust or ground cork may be mixed, may serve to quiet many a gear which has been worn to the point of extreme noisiness were not such precautions taken. A fault which might occur only at a certain engine speed, or under certain conditions of hill climbing, will probably not assert itself during a 15- or 20-mile test run—especially if the route chosen was suggested by the owner of the car.

The only accurate judge of the actual condition of a second-hand car is the owner who has driven it and cared for it during its preceding 2000 or 3000 miles of service. True, he may be biased, but he will know under what conditions its failings are most pronounced, and if he is a personal friend whose statements can be trusted, the chances of obtaining full value from the purchase of such a car are far better than were the selection made from among the stock of a less reliable second-hand dealer or professional trader.

Mileage Means Nothing.

The speedometer means but little in the selection of a used car. The figures may be moved backward to indicate less mileage than has actually been covered; the instrument may have been out of commission for several thousand miles; or a new "head" may have been installed sometime during the life of the car. On the other hand, the matter

of the actual mileage covered is not nearly so important as is the care the car may have received during its service. Fifty thousand miles of careful care and repair will not entail nearly the amount of wear that will result from one thousand miles of incorrect lubrication or adjustment.

Wrong to Judge by the Year.

One of the first questions asked by the purchasers of second-hand cars is, "What year is it?" If the owner tells him the truth and the car happens to be built some five or six years ago, the prospective purchaser will possibly attach less value to the car than if it had been built in 1917 or 1918. Such a wholesale basis for judging the value of used cars as a whole is wrong, however, for in the period before the war, materials of a higher grade were available than those entering the construction of many of the same cars built in 1917 or 1918. On the other hand, some manufacturers built certain series of cars which proved more successful than those produced in the preceding or the following year.

Cars that Are "Finds."

The used-car "trade" generally feels that it knows these years and series which bore the good and the bad reputation, but in the case of individual cars this should not enter too largely into the basis of selection. Good cars produced during the poor series, properly cared for, are frequent "finds" among the stock of a second-hand automobile dealer, and to condemn a car because others of the same generation possessed undesirable family traits, is a short-sighted policy. The car's defects inherent in the design as a whole should be taken into consideration, but possibly the installation of a new type of ignition, carburetor, or other device will overcome all such difficulties.

Judge It as a Machine.

What must be done is to judge the car as a piece of machinery not related to any other products of the same manufacturers bearing a good or a bad reputation.

Even more important than the mileage which a car has been run is the fact that we cannot judge the value of a car by its external appearance. A coat of well-applied paint or varnish; a new piece of linoleum on the floor board; a touch of enamel here and a vigorous polish there, give a car a deceptive spick and span appearance which will soon be belied in its operation.

Where to Look for Wear.

On the other hand, a steering wheel from which the varnish has been badly worn; holes in the floor board covering under the clutch or brake pedals, or the disappearance of the enameled surface in the neighborhood of the ignition switch and light buttons, will indicate mileage which the speedometer may not show. But, as we have pointed out previously, the distance covered plays but little part in the actual value of a car.

The engine, transmission and differential wear are often difficult to discover. The best-designed engine on the market, however, may be provided with a noisy valve mechanism, and even well-built gears may possess a hum or ring when in operation which will not necessarily indicate incorrect mechanical adjustment.

Try the Steering Gear.

On the other hand, the conditions of the steering gear and its connections constitutes a fairly accurate indication of the general distance which a car has been run and the care which it has received. Careless driving over rough roads will soon loosen the steering gear so that there will be a considerable amount of accumulated lost motion between the steering wheels and the road wheels. This will not necessarily be indicated by the distance which a steering wheel can be turned before an answering thrust can be induced in the road wheels, for an inch or so of "play" at the rim of the steering wheel often represents intentional design. This is different from looseness, however, which may easily be detected by a firm thrust in either direction while the road wheels are on the ground.

Play in the tie-rod, drag link and other connections in the steering gear may be determined easily by grasping one front wheel, holding it firmly on either side, and attempting to turn it on its steering knuckle in one direction or the other. Lost motion in these connections will be readily discernible by the feel of the wheel and the amount which it may be turned on the steering spindle without affecting the other road wheel or the steering wheel.

Listen!!!

Wear of the bearings of the engine can best be tested by an expert's ear when the engine is operated at various speeds and under different loads. An amateur, however, may be able to determine the wear by a vigorous use of the hand-crank, although the design which permits the hand-crank to turn the engine in but one direction limits its capacity as to tests of this kind.

How Much "Play"?

But little can be told of the condition of the transmission and rear axle by throwing the gear lever in high, jacking up one rear wheel and noting the amount of "play" possible before the engine will be turned over by the movement of the rear wheel. The number of gears and universals through which such motion is transmitted accumulate the actual amount of play induced to the point where, to the uninitiated, it might seem excessive. This might vary from an inch or two to one-quarter of a turn without indicating excessive wear.

If the wheels are left on the ground or the emergency brake set, the amount of lost motion in the universal shafts may be determined by an attempt to turn the propellor shaft in each direction. Universal shafts will wear rapidly if not properly lubricated, and while they may be able to give service under these conditions, a knock may be produced which an amateur might be unable to locate. All joints should have a certain amount of play or lost motion, but this should not represent more than ¼ inch measured on the circumference of the propellor shaft. This amount would be excessive for the universal joints alone, but the bevel gear and pinion at the rear axle will be included in the play, and the motion will, therefore, be increased.

Watch the Brakes.

One of the most important points to consider when investigating a second-hand car, and yet fortunately, one of the most easily remedied, is the condition of the brakes. There should be at least ⅛″ or $\frac{3}{16}$″ of the wearing surface remaining on the external brake band. The brakes should be operated to determine whether all the points have been properly lubricated and are not so badly worn as to prevent proper operation of this most important part of the car control.

After even the most rigid inspection of the used car, faults may develop which could not have been anticipated. This should, to a certain extent, discount the value of any used car. But we are assuming that any man who makes such a purchase does so with his eyes open, realizing that a used car under any circumstances is more or less of a "gamble," and that no factory should be condemned because of the poor performance of a second-hand car bearing its name.

SECTION X. SAVING THE CAR BY CAREFUL DRIVING

When you take your place behind the wheel of the modern automobile, you have at your command levers, pedals, buttons and switches, which, when properly controlled, will cause the car to do practically everything in the form of locomotion within the scope of the three known dimensions—and many an automobile driver may sometimes feel that he has discovered the mysterious fourth.

It is within this compartment that Fate determines the age—both in appearance and usefulness—that a car shall reach before its first or last journey to the repair shop or junk heap.

Don't Be "too Expert."

It is not our purpose to offer instructions in driving; we wish only to point out the harm that can be occasioned by ignorance, carelessness or a too-expert use of these controls at the disposal of the operator. We say "too expert" because it is often the experienced driver who, through contempt-breeding familiarity with the controls, becomes careless and feels that he is master of any situation which can arise. He it is, sometimes, who feels that a demonstration of experience and driving ability consists in rushing with full power applied to within a few feet of his stopping point, and then, with a grind and squeak of brakes and sliding of tires, coming to a sudden stop; who thinks that it is a mark of amateurism to be seen shifting his gears on a steep hill; who races his engine while idling at the curb, and listens with an "expert ear" to determine "how she is hitting." Such drivers are, in reality, far from being the expert operators which they believe, and each one of the previously-mentioned traits is an earmark of ignorance and inexperience of the rankest kind.

Assuming that you are a modest driver and are willing to learn from the experience of others what constitutes good car operation, let us visualize you as you sit in the driver's seat with your hand on the steering wheel; the spark and throttle levers within easy reach; the left foot close to the clutch—not resting on it; the right foot regulating the accelerator pedal, and yet ready for instant application to the brake pedal, and the right hand prepared for the automatic pull on the emergency brake in case of necessity, or easy grasp of the gear shift lever which, when properly synchronized with the actions of the right foot on the accelerator and the left foot on the clutch, results in perfect

shifting. In addition we will assume that your sense of hearing, as well as of sight, is on the alert, for the ears play an important part in the proper operation of the car.

How Driving Affects the Tires.

Important parts of the car most easily affected by the manner in which it is operated are the tires. The result of incorrect driving begins to be apparent in the condition of the tread almost from the first, and the man who jams on his brakes, skids around the corners, or spins his wheels, is certain to have a high bill for tire repairs at the end of the year.

When your right foot rests upon the pedal, you are placed in command of a mechanical apparatus which can cause the wheels to slide on dry pavement. Only the most serious emergency, however, should ever induce you to stop your car in this manner, and even then you should remember that the full braking effect is not obtained when the wheels are actually sliding. The brakes are so designed that they may be applied gradually, and if you will remember that a throttled engine offers a certain retarding effect, down to a speed of five or six miles per hour, and will keep the clutch in until the momentum of the car has been reduced to that speed, you will find a valuable supplement to the delicate operation of the brakes. The man who travels in this manner and anticipates the majority of his stops so that he can throttle his engine in time and partially coast to rest at the desired point, will add thousands of miles to the life of his tires, and will eliminate the necessity for frequent brake-lining renewals. Furthermore, the habit of driving in this manner is one of the best preventives of skids on slippery streets, for it is only the car on which the brakes are applied too suddenly that slips and swerves and slides.

Use of the Clutch.

Another important factor in tire life is the use of the clutch. The steam car has long been renowned for the long life obtained from its tires. This is not because of any reduced weight of running gear, but rather because of the smooth and even application of power. The driver of the modern car, however, has at his command a device which, when properly applied, can transform the impulses of the engine into the smooth application of energy to the rear wheels. But the clutch may be engaged too suddenly so that the full power of the engine is communicated to the rear wheels in a single instant and this naturally causes a jerk which is not only conducive to wear of the tires, but on the universal joints, shafts and transmission as well. The toe of the

left foot of the expert driver should be as delicate in its "feel" of the clutch action as are the fingers of the shaving hand of the barber. By adding to the engine speed gradually as the toe is applied to the clutch, a smooth increase of car speed, or acceleration, can be obtained. Here, however, is where the value of a good pair of ears comes into play, for if you have a delicate sense of hearing, you can immediately determine when the power is being applied to the rear wheels too quickly, and when they begin to spin faster than they can grip the road surface. Naturally, spinning wheels will never get you anywhere —except to the repair shop.

Don't Slip the Clutch.

In an earlier paragraph we referred to the proper position of the driver's left foot as being *near* the clutch pedal, except when the clutch itself is to be operated. If you are a nervous driver, this precaution is all the more necessary, for otherwise you will be continually pressing your foot against the clutch and unconsciously letting it slip. The modern clutch is designed to transfer the full amount of power without slipping, and yet is so delicate in its operation that the slightest pressure on the pedal will produce a release. A slipping clutch generates heat, and this produces wear and loss of power. The clutch is meant to slip only when starting from a position of rest, and here again your sense of hearing will determine from the sound of the engine whenever it is necessary to shift to a lower gear on a hill or during slow travel.

The same nervousness which may prompt the average driver to keep his foot on the clutch pedal is not so liable to result in partial application of the foot brake, because his right foot is otherwise engaged with the foot accelerator. Watch closely, however, to note that you have not left the emergency brake with its automatic ratchet locked in position, or otherwise you will be confronted with a constantly overheated engine and other evidences of undue load placed on the power plant.

Driving by Sound.

While it is true that the engine of the modern car, as a rule, outlasts the steering gear, rear axle and other parts of the running gear, this is largely because the engine receives a greater degree of attention. The engine, of course, is the most intricate and involved piece of mechanism on the car, and it should be treated accordingly. When your highly developed sense of hearing discovers decided evidences of labor, the spark should be retarded and the transmission shifted to a lower speed. But, on the other hand, your engine may be run at an injuriously high speed, especially during what you may think is a "test"

conducted while the engine is idling. This will serve no purpose, for the same conditions cannot be obtained when the engine is running with no load as are found when pulling the car up a hill or on the level, and consequently, a continual speeding-up of the motor while the car is at rest is merely another mark of rank amateurism on the part of the driver.

Don't Forget the Battery.

You have probably been aware of the care which you should give your battery. You have been told that it is merely a reservoir for the supply of current, and that it cannot give out more power than has been put into it. Possibly, however, you do not realize that the current required for starting is many times greater than that supplied by the generator when the engine is running. In fact, the engine must be run at a charging speed (which corresponds to about 20 miles per hour of car travel) for some 20 times longer than the time consumed in starting, before the amount of energy taken out can be resupplied. Consequently, you should prime your engine in cold weather so that it will start more easily, and should also be careful that you do not use your lights unduly if you are making only short daylight runs.

Good Rules.

The driver who realizes that his properly synchronized control of the levers and pedals is a factor which determines largely the amount of time which the car shall spend at the repair shop is the one who can obtain the most value from his automobiling experience. The rules are simple, and they may be briefly summed up as follows:

Coast to a stop; do not use the brakes unnecessarily. If the clutch is engaged and the engine throttled, the drag will serve as a brake down to a speed of 6 to 7 miles per hour.

Do not slip your clutch. Shift to a lower gear if the engine labors.

Do not race your engine at the curb. If you must test it, do so in a garage.

Do not drive fast around the corners. The better your car holds the road, the greater is the strain on the tires when rounding a turn.

Do not let your engine knock or labor. Retard the spark, shift to a lower gear, and have the carbon cleaned out at the first opportunity.

Do not waste your battery.

Do not let your engine overheat.

Observe these rules, and you, as the driver, will have done more to keep your car out of the repair shop than has the manufacturer with all of the knowledge and experience at his command.

SECTION XI. WHAT THE TIRES DO

Do you really know how much service you obtain from your tires? Your speedometer may show a certain number of miles that the car has been driven since a tire was changed. But you cannot actually realize the amount of work done until you take into consideration several conditions. For instance, the tire that is used only on smooth pavements and on level highways should be expected to give four or five times the service of the one attached to a car which is driven up and down steep grades and over frozen or rough roads.

The tires transmit the power required to keep the car in motion; they are belts which carry that power from the wheels to the road. It requires 15 times as much power to drive a 4000 pound car up a 20% grade at 20 miles per hour as it needs to maintain that speed on the level; consequently, under the former conditions, the tires are doing 15 times the work that they are called upon to perform on a level highway.

On the following pages, the power required to drive cars of different weights up various grades at different speeds ranging from 5 to 60 miles per hour, is shown. The zero grade is naturally the level. Under these conditions, only the power required to overcome the wind resistance, with the top and wind-shield up, is considered. Powers required to drive heavy cars up steep grades at high speeds which are greatly in excess of those found on the modern passenger car are eliminated. For example, it would be absurd to conceive of a 4000 pound car developing horse power in excess of 150.

Following the power table will be found several pages of records of tire service. One page should be reserved for each tire, and each time a change is made, the speedometer reading and the location should be entered in the proper column.

POWER REQUIRED TO CLIMB VARIOUS GRADES AT VARIOUS SPEEDS

Table I—2,000-Pound Car.

Percent of Grade.	Speed in miles per hour.								
	5	10	15	20	25	35	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	1	3	5	8	11	16	31	52	83
10	3	6	9	13	18	24	42	66	100
15	4	8	13	18	25	32	52	79	115
20	5	11	17	23	31	39	62	91	130
25	7	13	21	28	37	47	72	104	145
30	8	15	24	33	43	54	82	116	160
40	10	21	31	42	54	67	100	138	186
50	12	24	37	51	65	80	116	159	

Table II—2,500-Pound Car.

Percent of Grade.	Speed in miles per hour.								
	5	10	15	20	25	30	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	2	4	6	9	13	17	33	45	91
10	3	7	11	16	22	28	47	73	108
15	5	10	16	22	30	38	60	89	126
20	7	13	21	29	36	47	72	104	145
25	8	16	26	36	42	56	85	120	164
30	10	18	30	41	51	65	97	135	182
40	13	26	38	52	67	82	119	163	
50	15	30	45	63	80	98	140		

POWER REQUIRED TO CLIMB VARIOUS GRADES AT VARIOUS SPEEDS

Table III—3,000-Pound Car.

Percent of Grade.	Speed in miles per hour. 5	10	15	20	25	30	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	2	4	7	9	15	20	36	58	91
10	4	8	13	19	25	32	53	80	116
15	6	12	19	26	35	44	68	99	138
20	8	16	25	34	44	55	83	117	146
25	10	20	31	41	53	66	98	136	183
30	12	22	36	48	63	77	113	154	
40	15	32	46	62	79	97	139		
50	18	36	56	74	95	116	164		

Table IV—4,000-Pound Car.

Percent of Grade.	Speed in miles per hour. 5	10	15	20	25	30	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	3	5	8	13	18	23	41	65	99
10	5	11	17	24	33	40	63	93	132
15	8	16	25	34	45	55	84	108	162
20	11	21	33	44	57	70	104	143	
25	13	26	41	54	70	86	124		
30	15	29	47	64	82	100			
40	20	42	61	82	104	128			
50	24	48	73	99	125				

POWER REQUIRED TO CLIMB VARIOUS GRADES AT VARIOUS SPEEDS

Table V—5,000-Pound Car.

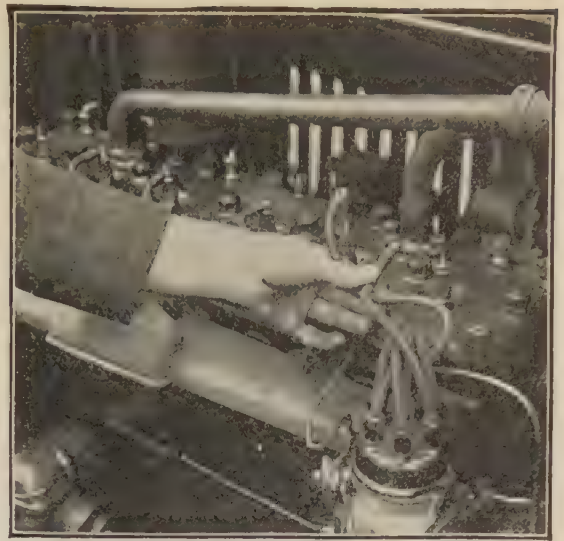
Percent of Grade.	Speed in miles per hour.								
	5	10	15	20	25	30	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	3	7	11	16	21	27	46	72	106
10	7	14	21	30	39	48	74	106	148
15	10	20	31	42	54	67	100	138	186
20	13	26	41	55	70	86	124	169	
25	16	32	50	67	86	105	152		
30	19	36	59	80	101	123			
40	25	52	75	102	127				
50	30	60	91	123					

Table VI—6,000-Pound Car.

Percent of Grade.	Speed in miles per hour.								
	5	10	15	20	25	30	40	50	60
0	**	.3	1	3	5	8	20	39	67
5	4	8	13	18	24	31	56	78	114
10	8	17	25	35	45	56	85	120	164
15	12	24	37	50	64	79	115	158	209
20	16	32	48	65	83	101	145	195	
25	20	39	59	80	102	125	175		
30	23	44	70	95	120	146			
40	30	63	90	121	154				
50	36	72	109	146					

HOME-MADE METHODS TO STOP THE CAR THIEF

A break in the ignition circuit and a switch plug placed in some unusual place, such as under the seat.



Moving ignition wires to the wrong plugs to cause misfiring in two or more cylinders.

Using a padlock to hold the steering wheel so it cannot be turned.

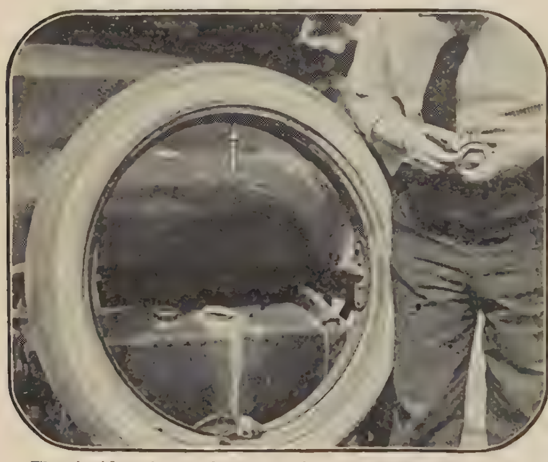
Using a padlock to hold the transmission in reverse and the starter pedal in "off" position.

Removing the rotor from the timer and replacing the cover.

IDENTIFYING YOUR CAR BY SECRET MARKS

Conceal your card in a small rip made in the upholstery. The upholstery can easily be sewed together again.

A few scratch marks on the gasoline tank gage will escape notice of the thief.



The inside of the filler cap is a convenient harbor for several secret marks.

A few prick punch marks on the inside of the hub cap will identify a car.

Making a few prick punch marks on the underside of the front axle where they would not be noticeable.

TIRE RECORD

USE ONE RECORD BLANK FOR EACH TIRE OF YOUR CAR AND SPARES

Make .... Mfrs. No. .... Size ....

Date Purchased .... Price ....

Position	Speedometer		Mileage	Remarks (Cause of Trouble)	Cost of Repair
	On	Off			

Total Mileage ....

Repairs $................

Price $................

Tire Cost per Mile $..........

Total Cost $................

TIRE RECORD

USE ONE RECORD BLANK FOR EACH TIRE OF YOUR CAR AND SPARES

Make .... Mfrs. No. .... Size ....

Date Purchased .... Price ....

Position	Speedometer		Mileage	Remarks (Cause of Trouble)	Cost of Repair
	On	Off			

Total Mileage ....

Repairs $................

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Total Cost $................

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TIRE RECORD

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Position	Speedometer		Mileage	Remarks (Cause of Trouble)	Cost of Repair
	On	Off			

Total Mileage ....

Repairs $................
Price $................

Tire Cost per Mile $..........

Total Cost $................

TIRE RECORD

USE ONE RECORD BLANK FOR EACH TIRE OF YOUR CAR AND SPARES

Make .... Mfrs. No. .... Size ....

Date Purchased .... Price ....

Position	Speedometer		Mileage	Remarks (Cause of Trouble)	Cost of Repair
	On	Off			

Total Mileage .... Repairs $.................

Price $.................

Tire Cost per Mile $.......... Total Cost $.................

"A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR"

LUBRICATION RECORD

Grease, Oil, or Inspect the Following

EVERY 100 MILES

(Speedometer Reading)
Mileage

Name of Part. (Check (√) under mileage when part is lubricated.)		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
Crank Case																													
Steering Knuckle	Right																												
	Left																												
Spring Shackle Bolts																													
Front Right Spring	Front																												
	Rear																												
Front Left Spring	Front																												
	Rear																												
Rear Right Spring	Front																												
	Rear																												
Rear Left Spring	Front																												
	Rear																												

Name of Part.		2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400
Crank Case																											
Steering Knuckle	Right																										
	Left																										
Spring Shackle Bolts																											
Front Right Spring	Front																										
	Rear																										
Front Left Spring	Front																										
	Rear																										
Rear Right Spring	Front																										
	Rear																										
Rear Left Spring	Front																										
	Rear																										

"A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR"

LUBRICATION RECORD

Grease, Oil, or Inspect the Following

EVERY 100 MILES

(Speedometer Reading)
Mileage

Name of Part. (Check (√) under mileage when part is lubricated.)		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
Crank Case....................																													
Steering Knuckle.........	Right																												
	Left																												
Spring Shackle Bolts																													
Front Right Spring....	Front																												
	Rear																												
Front Left Spring........	Front																												
	Rear																												
Rear Right Spring........	Front																												
	Rear																												
Rear Left Spring.........	Front																												
	Rear																												

Name of Part.		2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400
Crank Case....................																											
Steering Knuckle	Right																										
	Left																										
Spring Shackle Bolts																											
Front Right Spring.......	Front																										
	Rear																										
Front Left Spring.........	Front																										
	Rear																										
Rear Right Spring........	Front																										
	Rear																										
Rear Left Spring.........	Front																										
	Rear																										

"A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR"

LUBRICATION RECORD

Grease, Oil, or Inspect the Following

EVERY 500 MILES

(Speedometer Reading)

Name of Part. (Check (√) under mileage when part is lubricated.)		Mileage 500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10,000	10,500	11,000	11,500	12,000
Fan Bearing																									
Steering Arm	Front																								
	Rear																								
	Right																								
	Left																								
Clutch Yoke																									
Clutch Pedal Shaft																									
Brake Pedal Shaft																									
Emergency Brake Shaft																									
Internal Brake Rod Clevis Pins	Right																								
	Left																								
External Brake Rod Clevis Pins	Right																								
	Left																								
Internal Brake Cam Bearings	Right																								
	Left																								
External Brake Cam Bearings	Right																								
	Left																								
Brake Equalizer Bearings																									

"A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR"

LUBRICATION RECORD

Grease, Oil, or Inspect the Following

EVERY 500 MILES

(Speedometer Reading)

Name of Part. (Check (√) under mileage when part is lubricated.)		Mileage 500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10,000	10,500	11,000	11,500	12,000
Fan Bearing....................																									
Steering Arm..........	Front																								
	Rear																								
	Right																								
	Left																								
Clutch Yoke....................																									
Clutch Pedal Shaft..............																									
Brake Pedal Shaft..............																									
Emergency Brake Shaft..........																									
Internal Brake Rod Clevis Pins..................	Right																								
	Left																								
External Brake Rod Clevis Pins..................	Right																								
	Left																								
Internal Brake Cam Bearings..................	Right																								
	Left																								
External Brake Cam Bearings..................	Right																								
	Left																								
Brake Equalizer Bearings.......																									

"A MINUTE OF CARE IS WORTH AN HOUR OF REPAIR"

LUBRICATION RECORD

Grease, Oil, or Inspect the Following
EVERY 2500 MILES

(Speedometer Reading)
Mileage

Name of Part. (Check (√) under mileage when part is lubricated.)		2500	5000	7500	10,000	12,500	15,000	17,500	20,000	22,500	25,000	27,500	30,000	32,500	35,000	37,500	40,000	42,500	45,000
Front Wheel Bearings	Right																		
	Left																		
Rear-Wheel Bearings	Right																		
	Left																		
Generator	Front																		
	Rear																		
Starter	Front																		
	Rear																		
Timer																			
Steering Gear Case																			
Transmission																			
Differential																			
Universal Joints	Front																		
	Rear																		
Horn																			
Speedometer																			

INDEX

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